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Longang Gamo Saubaber

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REPUBLIQUE DU CAMEROUN

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UNIVERSITE DE DSCHANG

ECOLE DOCTORALE



REPUBLIC OF CAMEROON

Peace- Work- Fatherland

UNIVERSITY OF DSCHANG

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DSCHANG SCHOOL OF ECONOMICS AND MANAGEMENT
Laboratoire de recherche en Economie Fondamentale et Appliquée (LAREFA)

Three Essays on the Effects of Agricultural Land Expansion on Agricultural Sustainability in Sub-Saharan Africa

Thesis submitted in partial fulfilment of the requirements for the Award of a Doctor of Philosophy Degree (PhD) in Economics

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May 2023

The University of Dschang does not intend to give any approval or disapproval of the opinions expressed in this thesis. These opinions are to be considered as solely those of the author.

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Dedication

*My progeny Nayah Tsira, Samuel Ahmès, Amarah Céleste and
Constant of blessed memory.
This is the opportunity cost of my absence.*

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List of abbreviations

ACET	African Conference for Economic Transformation
AFS	Agri-Food Systems
AGRA	Alliance for a Green Revolution in Africa
AU	African Union
BII	Biodiversity Intactness Index
CBD	Convention on Biological Diversity
DGMM	Difference Generalised Method of moments
EBV	Essential Biodiversity Variables
ECOWAS	Economic Community of West African States
EKC	Environmental Kuznets Curve
ELD	Economics of Land Degradation
EMT	The environmental sociology ecological modernisation theory
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investments
FEMLOGIT	Fixed Effect Multinomial Logit
FIES	Food Insecurity Experience Scale
FSIN	Food Security Information Network
GDP	Gross Domestic Product
GLS	General Least Squares
GNI	Gross National Income
GVCs	Global Value Chains
HLPE	High Level Panel of Experts on Food Security and Nutrition
IFAD	International Fund for Agricultural Research
IFPRI	International Food Policy Research Institute
IIA	Independent or Irrelevant Alternative
ILO	International Labour Organisation
IPS	Im Pesaran and Shin
IUCN	International Union for Conservation of Nature
LLC	Levin Lin and Chu
LPG	Labour Productivity Growth
LPI	Living Planet Index
LSLA	Large-Scale Land Acquisition
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MLI	Modified Lilien Index
MNL	Multinomial Logit
NAV	Norm Absolute Value
NCAER	National Council of Applied Economic Research
NEPAD	New Partnership for African Development
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
PA	Population Average
PCA	Principal Component Analysis
PFGLS	Pooled Feasible General Least Squares
POMLOGIT	Pooled Multinomial Logit

REMLOGIT	Multinomial Random-Effects Logit
RLI	Red List Index
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling
SGMM	System Generalised Method of moments
SSA	Sub-Saharan Africa
TSC	Type of Structural Change
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNICEF	<i>Fonds des Nations Unies pour l'Enfance</i>
WCMC	World Conservation Monitoring Centre
WCED	World Commission on Environment and Development
WDI	World Development Indicators
WDPA	World Database of Protected Areas
WFP	World Food Program
WHO	World Health Organisation
WWF	World Wild Fund

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Abstract

The aim of this thesis is to analyse the effects of agricultural land expansion on agricultural sustainability in sub-Saharan Africa. Though it is a prominent feature of these countries, its effects on agricultural sustainability have not been examined yet enough. Increasing agricultural land is hypothetically linked with social responsiveness like food security, economic aspect like structural change and environmental aspect such as biodiversity. This thesis shows in three essays that, agricultural land expansion can influence the prevalence of undernourishment, promote virtuous structural change and cause mammal species extinction. A panel analysis is conducted over 1990–2018 for 41 sub-Saharan African countries. The first essay uses the Generalised Method of Moments (GMM), the second essay employs a Pooled Multinomial Logit (POMLOGIT) model and the third, a pooled – Averaged Model. In all essays of the thesis, the three respective research hypotheses are rejected. The results disclose that agricultural land expansion influences three dimensions of agricultural sustainability in sub-Saharan Africa: Firstly, an increase of agricultural land by 1% reduces the prevalence of undernourishment by 0.23%, and helps to curb food insecurity. Secondly, it increases the probability of experiencing industrial-oriented structural transformation by 1.312, but by 1.089 services-oriented structural change. It promotes favourable transfer of agricultural labour towards the industrial sector. However, it causes serious damages to biodiversity. It is found that an expansion of agricultural land by 1% significantly increases the risk of extinction of endangered species, especially endemic mammals, by 0.0543. Therefore, the valuable benefits of agricultural land expansion must be weighed against the negative environmental impacts of converting forests and other natural habitat for agricultural purposes, increased carbon emissions, loss of ecosystem services and biodiversity, risk of disease, and impacts on local livelihoods and customs. As a policy recommendation, states should improve and promote access to land for small and large farmers in high potential agricultural and low wildlife density areas, further support intensive and organic agriculture and increase the number of protected areas.

Keywords: *Agricultural land expansion, food security, structural change, biodiversity loss, sub-Saharan Africa.*

Résumé

L'objectif de cette thèse est d'analyser les effets de l'expansion des terres agricoles sur la durabilité de l'agriculture en Afrique subsaharienne. Bien que l'expansion des terres agricoles soit une caractéristique importante des pays d'Afrique subsaharienne, ses effets sur les piliers social, économique et environnemental de la durabilité de l'agriculture, mesurés par la sécurité alimentaire, le changement structurel et la biodiversité respectivement, n'ont pas été suffisamment examinés. Cette thèse s'organise en trois essais et montre que, l'expansion des terres agricoles peut influencer la prévalence de la sous-alimentation, promouvoir un changement structurel vertueux et provoquer l'extinction d'espèces mammifères. Une analyse de panel est menée sur la période 1990-2018 pour 41 pays d'Afrique sub-saharienne. Le premier essai utilise la méthode des Moments Moments Généralisés (GMM), le deuxième essai utilise un modèle *pooled multinomial logit* (POMLOGIT) et le troisième, un *pooled – Averaged Model*. Les trois hypothèses de recherche de la thèse sont rejetées. Les résultats révèlent que l'expansion des terres agricoles influence trois dimensions de la durabilité agricole en Afrique sub-saharienne : Premièrement, une augmentation des terres agricoles de 1% réduit la prévalence de la sous-alimentation de 0,23%, et contribue à freiner l'insécurité alimentaire. Deuxièmement, elle augmente la probabilité de connaître une transformation structurelle orientée vers l'industrie de 1,312, mais seulement de 1,089 vers les services. En effet, elle favorise le transfert de la main-d'œuvre agricole vers le secteur industriel. Cependant, elle cause de sérieux dommages à la biodiversité. On constate qu'une expansion des terres agricoles de 1% augmente significativement de 0,0543 le risque d'extinction des espèces menacées, en particulier des mammifères endémiques. Par conséquent, les précieux avantages de l'expansion des terres agricoles doivent être mis en balance avec les impacts environnementaux négatifs de la conversion des forêts et d'autres habitats naturels à des fins agricoles, l'augmentation des émissions de carbone, la perte de services écosystémiques et de biodiversité, le risque de maladie et les impacts sur les moyens de subsistance et les coutumes locales. En guise de recommandation politique, les États devraient améliorer et promouvoir l'accès à la terre pour les petits et grands agriculteurs dans les zones à fort potentiel agricole et à faible densité de faune sauvage, soutenir davantage l'agriculture intensive et biologique et augmenter le nombre d'aires protégées.

Mots clés : *Expansion des terres agricoles, sécurité alimentaire, changement structurel, perte de biodiversité, Afrique subsaharienne.*

GENERAL INTRODUCTION

1.1. Context of the study

The role that land plays in agricultural production is relevant to any study of agriculture and development. Economists have always considered land as a key factor in solving countries' 'food problem'. Though it helps to support the productivity of human efforts and agricultural growth (Schultz, 1951), it also has a key role in development challenges (Johnson and Vollrath, 2020). Moreover, 'land is foundational to entrepreneurship, capital accumulation and wealth formation; therefore, the long-run prosperity of society depends on how well we manage this resource whose use is not always reversible' (Barlowe et al., 2014).

In economic thought, there are major controversies on the effects of agricultural land expansion. It is the only wedge of economic progress and the base of state organisation (Boulding, 1992; Cantillon, 1755; Quesnay, 1758), responsible for economic growth (Barbier, 2020; Ricardo, 1817; A. Smith, 1776), economic rent (James Anderson, 1777; D. Ricardo, 1817; A. Smith, 1776; Steuart, 1767; Turgot, 1793), but can cause damages to nature (Kuznets, 1955; J. S. Mill, 1848; Perrings and Halkos, 2015), is a factor of little importance that can be substituted by other factors (Patinkin, 1973).

Firstly, the two pre-classical schools have contrary views. Both mercantilism and physiocracy recognise the importance of agricultural land but at different stages. Land is of equal importance to work for mercantilism (Cantillon, 1755; Daniel, 2010). According to this school, the bases for economic prosperity are population, extractive industries and growth of agricultural output and land. In feudalism, land is at the core of the feudal order. It constitutes the basis of the military, judicial, administrative, and political system (Polanyi, 1957).

Physiocrats, however, attribute their economic surplus and agricultural product to agricultural land. It is a reservoir of wealth comprised of abundant and diversified food from farming activities (Boulding, 1992). The essential means through which a nation can derive agricultural surpluses (Quesnay, 1758), and improve on the living standards of her citizens. Meaning that agricultural land ensures food production and stabilises the food chain hence, conquering new lands for agriculture means progress.

Classical economists consider two additional factors namely capital and labour, but still attribute an important role to agricultural land, as a factor of production. Expanding land for cultivation means increasing both output and wealth (A. Smith, 1776; Steuart, 1776, Turgot, 1793), and can also cause

changes in the natural environment (J. S. Mill, 1848). Though, in that school there is not unanimity concerning the returns to scale of land and the effects of agricultural land expansion.

For instance, agricultural land is considered as the principal source of revenue and wealth of every country and agricultural land is assumed to have increasing returns (A. Smith, 1776). Conversely, land is said to have decreasing returns called either extensive margin (Steuart, 1776) or intensive margin (Turgot, 1793). The extensive margin of Steuart holds that as population increases, it leads to the use of poorer and poorer soils, and productive efforts then produce smaller and smaller returns. On the other hand, Turgot's intensive margin states that as equal amounts of capital or labour are successively applied to a given piece of land, the level of output derived from each application will first increase towards its maximum, and then decrease, and finally converge towards zero (Schumpeter, 1981).

Another critical divergence under the classical school of thought concerns competition with the natural environment. Theoretically, land expansion for agriculture appears to conflict with natural beauty. The prosperity functions of land in providing food and precious materials are opposed to nature's amenity services. Taking up additional hectares of land does damage to the natural beauty, natural habitats, and the pleasures of the diversity of both animal and plant species (J. S. Mill, 1848). However, the impact of agriculture on biodiversity depends on the extent and types of agriculture and the degree to which agricultural land contrasts with the natural ecosystem (Wilson et al., 2020).

Neoclassical economists posit substitutability between human-made and natural capital and refute the importance of agricultural land expansion. This led to a production function of the form: $Y=f(K)$. Therefore, land was found to be a valueless factor of production and agricultural land must be developed and maintained, just like any other capital asset (Patinkin, 1973).

Although it has been efficient and useful for allocating land resources in the short run, the neoclassical economic approach to land has received several criticisms. For instance, the inadequate treatment of aspects such as irreversibility, non-substitutability of production factors, and the pervasiveness of external effects, means neglecting the unique services land provides, which are not traded in markets (Hubacek and van den Bergh, 2006).

Agricultural economics is the original farm management tradition, developed to help farmers gain a satisfactory income from their land (Fox, 1987). Land economics differs from agricultural economics in that it retains the classical view of the uniqueness of land resources, and stresses the factor land, rather than its management (Hubacek and van den Bergh, 2006; Renne, 1947).

As land suitable for agriculture is not constant over time (Hubacek and van der Bergh, 2006) and farming land often creates negative externalities (Abler et al., 1999), one of the early research questions in land economics is how optimally bring unused lands into agricultural production. With a seeming abundance of agricultural land, the interest shifted to the more general concern about situations in which land, its use, or its limitations was of strategic importance. Salter (1942) focused on changes in major land uses and their effects on social well-being. A subject that has received little attention until date (Maehle et al., 2020; Opp, 2017).

After years of treating land as a secondary resource that could be subsumed under other types of capital, economic theorists recognise that land expansion for agriculture can have effects on outcomes such as food production, labour spillovers, better living conditions for rural populations and biodiversity change. Land and agricultural economists guide government regulations in finding 'more appropriate balances between public and private ownership' (Gnedenko, 2020) that favour agricultural sustainability.

This study's conceptual plan contains several approaches and definitions of the main notions. The concepts are agricultural land expansion, sustainability of agriculture, food security, structural change and biodiversity. Therefore, it is essential to discuss and clarify the concepts and links between agricultural land and agricultural sustainability.

Agricultural land expansion refers to the increase in agricultural land. In general, 'agricultural land' is the land resource upon which agriculture takes place for the production of food and fibre, including croplands, pastures, orchards, groves, vineyards, nurseries, ornamental horticultural areas, confined feeding operations, and other use applications (Qi, 2014). Lyuri and Lands (2008) consider that agricultural lands consist of three main types: arable land (including cropland and fallows), land under permanent crops, and pastures and hayfields.

The analysis of the concept of agricultural land expansion split the empirical literature into two while considering its sources. The first wave points out the intranational view of agricultural land expansion. Here, authors (Barbier, 2020, 2021; FAOStat, 2013; Keating et al., 2014) consider the Ricardian sense of agricultural land expansion. It refers to an increase of the extensive margin of farmland, which comes from the household and the farmer. It is also termed as extensive growth of agriculture (Perrings and Halkos, 2015), frontier expansion or extensification (Dawson et al., 2016; Wilson et al., 2020), land use change (Mora et al., 2020) or simply agricultural expansion (Laurance et al., 2014). The terms agricultural land expansion and agricultural expansion are used interchangeably in this thesis.

However, a second wave emphasises on the foreign origins of agricultural land expansion. Authors refer to this as agricultural land acquisition or large-scale land acquisitions (Mechiche-Alami et al., 2021; Santangelo, 2018), land use cover change (Degife, 2020), international land deals for agriculture (Nolte et al., 2016) or large-scale agricultural investments (LSAIs) (Nolte and Ostermeier, 2017). In that case, the sources of expansion are foreign countries through land deals or acquisitions by foreign countries or foreign direct investments. This analysis differs from this conception because it focuses on endogenous land expansion, which has not been thoroughly explored. Using the Ricardian sense of agricultural land expansion, the study seeks to analyse the global effects of land expansion on agricultural sustainability.

The expression agricultural sustainability, incorporates two important terms: sustainability and agriculture. In order to understand sustainable agriculture, a clarification of the concept of sustainability is needed. Sustainability means meeting the needs of the present without compromising that of the future generations (Chandan and Das, 2017; Mota and Scott, 2014; White, 2013). The understanding of the sustainability concept varies according to authors perception, who represent different models¹. Three models² of sustainability are presented here: the egg of sustainability, the prism of sustainability and the three pillars basic model.

Firstly, the 'Egg of Sustainability'. Also known as the dependency model, which was designed in 1994 by the International Union for the Conservation of Nature, IUCN (Guijt and Moiseev, 2001). It demonstrates the relationship between people and ecosystems as one circle inside another. This traduces the reciprocal links between people and ecosystems. People are within the natural environment, and depends entirely on other. Social and economic development can only take place if the environment offers the necessary resources: raw materials, space for new production sites and jobs, constitutional qualities (recreation, health, etc.). The ecosystem is therefore to be regarded as a super-coordinated system to the other dimensions of the triangle or prism models: social, economic, and institutional. This model is not used in the study as it does not assess the links between one dimension and the other. The study, however, aims to investigate how land expansion phenomenon affects the three dimensions (Herath and Rathnayake, 2019).

Secondly, the prism of sustainability. This is a four-dimension model. It is developed by the German Wuppertal Institute and defines sustainable development using the following components: economy, environment, society, and institutions. There are a number of inter-related dimensions in this model,

¹ For a more detailed description of models of sustainable development see Herath and Rathnayake, (2019)

² For convenience reasons, figures of the two first models are presented in the appendix, in figures 26 and 27 respectively.

including care, access, democracy, and eco-efficiency that can lead to policy changes. The main critic of this prism theory argues that ‘the economic dimension tends to include assets emanating from all four dimensions, thus, adding confusion to the description and analysis’ (Keiner, 2005). Moreover, how agricultural land expansion affects institutions outreaches the framework of this study, making the theory unsuitable for this study.

Finally, the three pillars basic model or the three interlocking circles model. This model is among the most widely known models in the field, using three dimensions: economy, environment and society as dimensions. The figure shows three interlocking circles with the triangle of environmental (conservation), economic (growth), and social (equity) dimensions. Sustainability is modelled on these three pillars. This model is based on considering the society, but does not explicitly take into account ‘human quality of life’ (Hamedani, 2014). The second problem associated with the model is that it does not incorporate a time dimension which is a core component of the World Commission on Environment and Development (WCED, 1987) definition (Thatcher, 2014; Thatcher and Yeow, 2016). The study overcomes the first limit by using an indicator of the social dimension which is the least developed (Maehle et al., 2020; Murphy, 2012) and the second limit by using time-series data, to evaluate the effects of agricultural land expansion on sustainability of agriculture.

Sustainable agriculture is not an arbitrary concept. Any attempt to seek a single correct universal definition fruitless (Oberč and Schnell, 2020; Siebrecht, 2020). There is a plurality of definitions, which stem from both the epistemological divergences of the concept of sustainable development, and from the different normative or positive principles, underlying the concept of sustainable agriculture. The definition of sustainable agriculture can be adjusted to the respective contexts (Trigo et al., 2021), even though there are three main standpoints by which authors understand sustainable agriculture: On the one hand, it is interpreted as an approach or a philosophy motivated by an awareness of the negative impacts of agricultural activities. On the other hand, it is perceived as a set of strategies that should be applied to enhance resilience (Hansen, 1996; Thompson, 2007; Trigo et al., 2021). Lastly, agricultural sustainability is understood both as a philosophy and system of farming.

Firstly, the farming system approach or the ‘goal-prescribing approach’ (Siebrecht, 2020) or ‘mean oriented’ (Binder et al., 2013; Deytieux et al., 2016; Silva and Marta-Costa, 2013). Goal-prescribing concepts interpret sustainability as an ideological or management approach. It stresses the adaptability, resilience or reproducibility of agricultural inputs and results. Here, certain types of management, measures, or prescribed techniques are defined as sustainable in general. As long as these requirements or standards are met, sustainability is assumed (Siebrecht, 2020).

Some definitions falling under this category consider sustainable agriculture as agriculture that is based on viable, liveable, transferable and reproducible farms (Landais, 1998). A system capable of maintaining its productivity when subjected to severe stress or disturbance (Conway, 1985), to last into the future (Hansen and Jones, 1996), without excessive degradation of other ecosystems (Dover and Talbot, 1987; Edwards, 1987), where the resources used for production are conserved in a way that is more or less self-sustaining and competent to be part of a process of continuous improvement beyond conventional approaches (Rodale, 1988), and which favours dependence on chemical inputs (Reganold et al., 1990; Zahm et al., 2015).

The second approach is ideological and considers agricultural sustainability as a system-describing approach (Siebrecht, 2020). It supports the concept of sustainable agriculture that aligns with sustainable development. From this view, agriculture fulfils different or conflicting goals, over time ('goal-oriented'). Thus, this understanding of sustainability is related to the 'competing objectives' view of sustainability, where the focus is on 'balancing social, economic, and ecological goals' (Siebrecht, 2020, Hansen, 1996; Farrell and Hart, 1998).

From this viewpoint, Francis (1990) and MacRae et al. (1990) define sustainable agriculture as a philosophy based on human goals and values that reflect a state of empowerment, responsibility, and awareness of ecological and social issues. This philosophy guides the application to create resource-efficient agriculture and equitable farming systems. In this case, sustainability is an ideal state, and the more goals an agricultural system can achieve, the more sustainable it will be (Siebrecht, 2020).

From the literature, two subcategories of definitions are identified: The first subcategory gathers authors who define agricultural sustainability in relation to two dimensions of sustainable development: on the one hand, the social and environmental dimensions (CGIAR/TAC, 1988; MacRae et al., 1989), on the other hand, the environmental and economic dimensions (Godard and Hubert, 2002).

The second subcategory comprises authors who perceive the philosophy of agricultural sustainability from three dimensions: It considers sustainable agriculture as ecologically sound, economically viable, socially just and humane agriculture (Zhang et al., 2021), which over the long term, improves the quality of the environment and the resources on which it depends, provides basic food and fibre needs for people, improves the quality of life for farmers and the rest of society (American Society of Agronomy, 1989), ensuring an equitable supply between and within countries (Bonny, 1994; Brodhag, 2000; Otchia, 2014; Yang and Zhu, 2013; Zhang and Diao, 2020).

The third approach integrates the previous two approaches. Here, sustainable agriculture is both farming practices and philosophy³. It comprises a set of agricultural practices, backed by strong principles, philosophical and theoretical standpoints. It involves many concepts like agroecology, permaculture, ecological, and sustainable intensification.

The first and third approaches are hinged on operations, agricultural practices, management and sciences at farm level; the practices of plant growing, animal rearing and input management are at the forefront of these approaches. Our study does not analyse farming practices and farm management at the individual producer level. Nevertheless, this thesis is to investigate on the effects of agricultural land expansion on sustainable agriculture, as the latter could easily be measured in a macroeconomic analysis.

Thus, the philosophical definition of agricultural sustainability is more relevant to the study. Indeed, it incorporates the three dimensions of sustainability: social responsibility (human health, nourishment), economic viability (development, thriving economy...), ecological soundness (ecosystem function conservation, natural resource conservation) (Velten et al.; 2015; Runowsky, 1999; American Society of Agronomy, 1988; Hardwood, 1990). Hence, sustainable agriculture is a commitment to satisfy human food and fibre needs and to enhance the quality of life for farmers and society as a whole, now and into the future (Bird and Ikerd, 1993).

This thesis assesses the effects of agricultural land expansion on agricultural sustainability in sub-Saharan Africa. To achieve this aim, the thesis will examine how land expansion for agriculture affects the social responsibility, economic viability, and ecological soundness of agriculture in the region.

Many indicators are used to capture the social, economic, and environmental dimensions of agriculture in the literature. To start with, the social dimension of agricultural sustainability. This dimension tends to address issues related to social justice and social inclusion, such as better education and health (Halişçelik and Soytaş, 2019). At the micro level, it focuses on aspects such as the level of education, training, basic needs, and cultural values. However, at the macro level, it focuses on aspects such as the distribution of income and assets, achieving full and productive employment and decent work for all, with equal pay, eradicating forced labor and human trafficking,

³ Agroecology, nature-inclusive agriculture, permaculture, biodynamic agriculture, organic farming, conservation agriculture, regenerative agriculture, carbon farming, climate-smart agriculture, high nature value farming, low external input agriculture, circular agriculture, ecological intensification, sustainable intensification. Definitions of these concepts, and how they are linked to sustainability, are sourced from (Oberč and Arroyo Schnell, 2020), though it is not always easy to know what each term refers to - whether it is an approach, a practice, a set of related practices, an activity or tool, etc... For more details see Oberč and Arroyo Schnell (2020).

and political inclusion of all, food security (Maehle et al., 2020). Sub-Saharan African countries host one-third (282 million) of the world's undernourished, and the highest level (66.2%) of food insecurity according to the moderate and severe food insecurity (Sachs et al., 2021). Due to these poor statistics, the study tries to shed more light on the relationship between agricultural land expansion and food security. There are similar studies (Kinda and Badolo, 2019; Mechiche-Alami et al., 2021; Mughal and Sers, 2020; Santangelo, 2018) carried out in this domain.

Looking at the economic dimension of agricultural sustainability, broadly, it focuses on maintaining economic growth and encompasses high income levels (Halisçelik and Soytas 2019). Many indicators are found under the economic dimensions of agricultural sustainability such as eradicating poverty, productivity of small-scale farmers, women's access to ownership over land and financial services, higher levels of agricultural productivity (Maehle et al., 2020).

African states are known for experiencing fragile economic growth, due to labor moving toward the service sector (CUA and OECD, 2018). As structural change and economic growth are twins (Gabardo et al., 2017), it appears obvious that an effective structural change can make nations being more prosperous, while a bad structural change leads to a reduction in national income (McMillan et al., 2014). Few studies (Barbier 2020; 2021) show that agricultural land expansion promotes economic growth and few other studies (Baymul and Sen, 2020; Mensah et al., 2016) relate agricultural land to structural change. Hence, structural change is used to capture this economic dimension.

Thirdly, the environmental dimension of agricultural sustainability is based on the notion of ecosystem services. Ecosystem services are both renewable and non-renewable resources and waste absorptive capacity that provide benefits to humans and thus improve their welfare (Moldan et al., 2012). Environmental sustainability involves maintaining these services and, consequently, living within the limitations of the biophysical environment. Environmental sustainability involves maintaining these services and, consequently, living within the limitations of the biophysical environment. Some targets falling under the environmental dimension of agricultural sustainability include ensuring resilient agricultural practices that help maintain ecosystems and strengthen capacity for adaptation to climate change; Increasing the share of renewable energy; protecting and safeguarding the world's cultural and natural heritage; preventing or reducing pollution or depletion of natural resources (Maehle et al., 2020).

The rate of biodiversity loss is critical in sub-Saharan African (SSA) countries. Indeed, known as the first reservoir of biodiversity, forest losses operate at the rate of 4 million ha/year (FAO and UNEP, 2020). Moreover, 80% of deforestation originates from agricultural expansion. In addition, the

decline of species is alarming, with a decrease of 65% in population sizes of mammals, fish, amphibians and reptiles. On top of that, 50% of Africa's bird and mammal species could disappear by 2100 (Almond et al., 2020). Few studies (Balima et al., 2020; Perrings and Halkos, 2015; Tan, Chen, et al., 2022; Ullah and Kim, 2021) investigate the relationship between agricultural land expansion and biodiversity change. The study seeks to contribute to this literature.

The concept of food security has several definitions. Looking at the dimensions they take into account, the first definitions emphasise explicitly on the access dimensions: food security for a household means access by all members at all times to enough food for an active, healthy life (Reutlinger, 1986); The second considers production dimensions and stability as well: the amount of food in a country or area through all forms of domestic production, imports, food stocks and food aid (World Food Programme, 2006). Other approaches to food security emphasize accessibility more than availability. Food must be available at the immediate neighbourhood of all households. It is a basic human condition that exists when all people, at all times, are free from hunger (Drèze and Sen, 1991), or have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Pérez-Escamilla, 2017; Pinstруп-Andersen, 2009).

More elaborated approaches to food security enumerate five essential components: availability of food, its access, the utilisation of food, the sustainability of the food system providing these components and its stability (Timmer, 2017b) or the notorious five principles – universality, stability, dignity, quantity and quality – of McKeown (2006). Concerning the dimensions of food security, the access dimension fits with the study. Two reasons can be given. First, access to economic resources constitutes one of the key components of the social dimension of sustainability (Maehle et al., 2020). Thus, for agricultural sustainability, access to food should be prioritised. Second, while farm productivity in Africa is high, more than one third representing 282 million people of the world's undernourished is found in SSA (Sachs et al., 2021).

On the other hand, food security can be defined at three levels: individual and household level, national and global levels (Berry et al., 2015; World Food Programme, 2006). In a household, food security refers to the existence of adequate sources of food and the ability to acquire them to maintain an adequate nutritional intake for an active and healthy lifestyle (World Food Programme, 2006).

According to Smith et al. (2013) is the nation's ability to ensure uninterrupted arrangements of food supply so that the dimensions of food security are accessible to all citizens in both normal and emergency situations if any. Global food security is the assurance of an adequate food supply or access for all humans on earth. It essentially means equal distribution of food among the nations

irrespective of their economic status, regional disparities and sociocultural variations in a sustainable and eco-friendly manner (Mishenin et al., 2021)

In this study, we adopted the national view of food security that fits better with the analysis of sub-Saharan African countries. In summary, this work considers only the access dimension of food security at the national level. This is captured at national levels by undernourishment prevalence. That it provides a deeper and more coherent analysis of food security (Soriano and Garrido, 2016). If food security is ensured, it may lead to structural change as labour force will leave the agricultural sector (Timmer, 2017a).

The notion of structural change is not different from structural transformation in the present study. The classical sense of structural transformation as defined by (Lewis, 1954) and Kuznets (1955) refers to the movement of population and economic activity from low productivity to the more productive industry sector (Kanbur, 2017) and then from industry to services (Herrendorf et al., 2013). It is referred as the reallocation or natural rearrangement of economic activity across the three main sectors that eases the process of modern economic growth (Bloem, 2019; Gabardo et al., 2017; Herrendorf et al., 2013).

Countries do not follow the same types of structural changes (Bah, 2011). While developing countries may experience a 'bypassing' (Cadot et al., 2015) or growth reducing (McMillan et al., 2014) structural change, where labour moves from high to low productivity sectors, others may have a classical or growth enhancing structural change, where labour moves in the opposite direction and contributes positively to overall productivity growth.

Labour-oriented definitions consider structural change as the movement of labour from agriculture to either industry or service sectors (Bloem, 2019) or the movement of workers from low productivity to high productivity activities and sectors (Baymul and Sen, 2020). When agricultural labour migrates toward a sector of higher productivity, it is called virtuous structural change. Meanwhile, when agricultural labour moves toward a sector of lower productivity, it is termed as vicious structural change with dynamic losses (de Vries et al., 2015). Because the scope of the work is in sub-Saharan Africa, the labour oriented definition of Bloem (2019) is adopted as it fits well with the African context. The economic growth through structural change can provoke biodiversity loss.

The definition of biodiversity given by the Convention on Biological Diversity in 1992 is enounced as follows: '*Biological diversity means the variability among living organisms from all sources, including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; these include diversity within species, between species, and of ecosystems*'.

Strictly speaking the word biodiversity refers to the quality, range or extent of differences between biological entities in a given set. In total it would thus be the diversity of all life and its characteristics (S. R. Singh, 2022).

Literature identifies three types of diversity, from micro to macro: genetic diversity, species diversity, and ecosystem diversity (Dasgupta, 2021; Iritie, 2015; Kontoleon et al., 2007; S. R. Singh, 2022). Firstly, genetic diversity refers to the information contained in the genes of individual plants, animals, and microorganisms. Species diversity is the diversity of species within which gene flow occurs under natural conditions. No two individuals of the same species are exactly alike. For instance, humans have a lot of genetic diversity between themselves. People living in different areas show a high level of difference. Genetic diversity is related to the diversity of genetic information stored in each species (Dasgupta, 2021; Kontoleon et al., 2007; Singh, 2022). Secondly, species diversity is related to the richness and abundance of species. It is the biodiversity seen within a community. It signifies the number and distribution of species. The number of species in an area varies broadly according to the environmental surroundings or ecosystems (Iritié, 2015; Kontoleon et al., 2008). Generally, the greater the species richness, the greater is the species diversity (Singh, 2022). The third type of biodiversity is ecosystem diversity. This type of biodiversity is related to the variability of ecosystems. It refers to the diversity seen between the ecosystems in a region. Several ecosystems, such as rainforests, deserts, mangroves, etc., show a vast diversity of life forms living in them (Iritié, 2015; Kontoleon et al., 2008).

A second diverging conception of biodiversity measures is based on spatial scales (Whittaker, 1975). Three terms for measuring biodiversity are formulated: alpha, beta, and gamma diversity. Firstly, alpha diversity or within habitat diversity. It characterises diversity within a particular habitat or ecosystem. It is expressed as the species' number per unit area. Secondly, beta diversity or between-habitat diversity, referring to species diversity between two habitats or ecosystems when compared. Thirdly, gamma or regional diversity known as the total species diversity in a landscape.

However, this work focuses on African states. Alpha, beta, and gamma diversity do not coincide sharply with state boundaries. Moreover, due to the lack of spatial data, this spatial scale description is not in line with our research. In biodiversity economic literature, it is difficult to capture genetic and ecosystem biodiversity because of their complexity. However, biodiversity of species receives more attention (Balima et al., 2020; Dasgupta, 2021; Dietz and Adger, 2003; McPherson and Nieswiadomy, 2005; Perrings and Halkos, 2015; Tan, Chen, et al., 2022). Indeed, species richness, or the number of species present in per unit area is the simplest measure of species diversity (Singh,

2022). This indicator allows to capture biodiversity change, and to evaluate the effects of agricultural land expansion on the reduction of wildlife.

Although agricultural land expansion has many causes, it also has links to the three dimensions of agricultural sustainability. Figure 1 illustrates how land expansion is connected to agricultural sustainability dimensions.

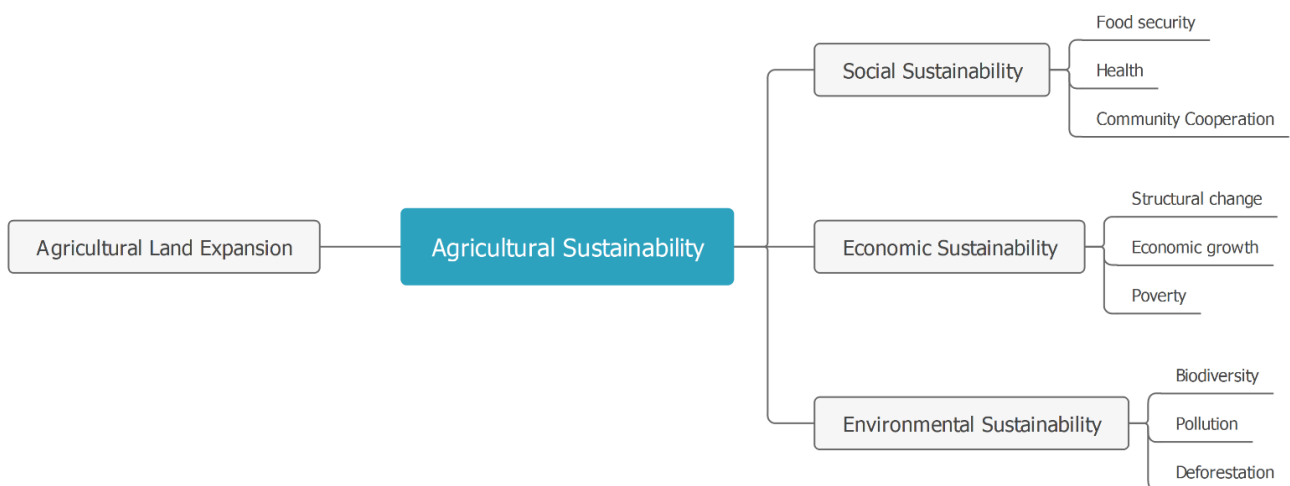


Figure 1: Conceptual model
Source: Author

Building such a conceptual model has a double aim. First, it helps to have a better representation and understanding of the structure and completeness of the study itself. The expansion of agricultural land may influence the continent’s ability to deal with its food production problems. Dealing with food security is a good cause of structural transformation, as it may propel farmers in other sectors as workers. However, it will also cause changes in the natural habitat of many species and biodiversity. Thus, land expansion has important social, economic, and environmental effects in nations (Lanz et al., 2018) and the achievement of one objective may affect that of the others. This reveals the need for authorities to balance different interests of agricultural sustainability (Williams et al., 2021), because economic growth alone, for instance, cannot be considered as a success, unless it leads to a more equal income distribution (Halisçelik and Soytaş, 2019) or exceeds the planet’s ecological limits (Dasgupta, 2021).

The interactions between agricultural land and the three dimensions of sustainable agriculture make it possible to assess the effect of the former on these important components. The analysis of these effects would constitute an important key for the establishment of new integrated and optimal policies, as well as the understanding of this factually increasing phenomenon.

In the empirical literature, agricultural growth comes either from intensification or extensification; intensifying the use of the existing cultivated area and increasing the extensive margin, that is, the expansion of agricultural land (Barbier, 2020; Keating et al., 2014; FAOStat, 2013).

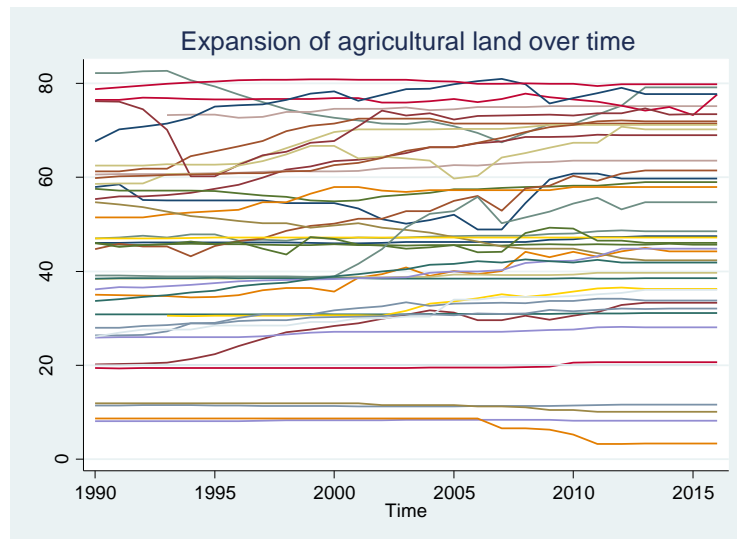


Figure 2: Trends in agricultural land in Africa countries

The stylized facts about land expansion show that agricultural land expansion is an actual phenomenon in Sub-Saharan African (SSA) developing countries. The total area of agricultural lands in the world is 4,973.4 million hectares (ha). They cover 33.3% of terrestrial surface, including 10.3% of arable land and land under permanent crops and 23% of pastures and hayfields. However, SSA is the most land abundant region of the world with roughly 60% of the world’s uncultivated arable land (African Center for Economic Transformation (ACET), 2017). In 1961-70, the surface of arable land and land under permanent crops was estimated at 136.66 million hectares (mHa) and increased to 194 mHa in 2001-08, representing a 42% increase (Fuglie and Rada, 2013; Lyuri, 2008).

Similarly, the crop area shares of total area harvested rose by 89%, from 92.73 to 175.08 million ha. It also represents an annual increase of 1.76 million ha over the same period. More specifically, land under permanent crops increased by almost 67%, moving from 12.58 mHa in 1961-70 to 20.95 mHa in the 2001-08 decade. Looking at land under permanent pasture, it shows a slower increase of only 6% within the same period, which translates to a growth of 0.89 mHa each year. In SSA, between 1961 and 2010, arable land and permanent crops rose by almost 60%, from about 144 to 230 million hectares, permanent meadows and pastures went from 801 million to 827 million hectares; forest areas decreased by 10%, from 741 million hectares in 1990 to 666 million hectares in 2010 (Fuglie and Rada, 2013).

Despite a general positive trend (figure 2), stylized facts show some heterogeneities in **countries'** agricultural land expansion. As a matter of fact, in 2007, countries like Burkina Faso, The Gambia,

and Malawi, Sierra Leone in 2012, and Lesotho in 2015 have recorded an increase of more than 5 percentage points of agricultural land. Since 2014, Lesotho, Nigeria, and South Africa have 75 percent of their land area occupied by agricultural land. However, countries like Cameroon, Gabon, and Liberia have less than 30% of their total land area used for agricultural purposes (WDI, 2021).

Although demand for new agricultural land among most low- and middle-income countries shows little sign of debilitation, agricultural land remains highly demanded. Over the period 1970–2016, agricultural land area in low- and middle-income countries rose by 16% and by 15% in Sub-Saharan Africa (Barbier, 2021). After independence, country development policies through agricultural green revolutions have contributed to the expansion and increase in agricultural output in Africa (Dawson et al., 2016). This was in conformity with the policies of the African Union and NEPAD. The latter have included access to land, equitable distribution, security and tenure, cultivation of new varieties, irrigation, and sustainable intensification in their policies (AGRA, 2013).

Today, the conflict between Russia and Ukraine is causing the world to experience unprecedented food crisis. This poses major threats to developing countries, challenges agricultural sustainability, and calls for more solidarity between nations. To withstand the crisis at least in the short run, it is necessary to expand agricultural land to increase food and cereal production in sub-Saharan African countries (Macron, 2022).

Although non-exhaustive, other factors identified as causes of land expansion include institutional factors like population dynamics and government policy (Hye and Khan, 2010; Jellason et al., 2021), ill-defined property rights and open access conditions (Barbier, 2004a; Barbier and Burgess, 2001; Juniyanti et al., 2021; Kaimowitz and Angelsen, 1998), more secure rights over land (Besley, 1995; Bohn and Deacon, 2000; Feder and Feeny, 1991; Meyfroidt et al., 2022), and tenure insecurity (Kontoleon et al., 2007; Mosisa and Asefa, 2022). In addition to the above, poor intensification, low agricultural performance, low input utilisation, food and cash crop production (Jellason et al., 2021; Keating et al., 2014), agricultural prices, fertiliser use, irrigation and technology (Hye and Khan, 2010; A. P. Singh and Narayanan, 2013), change in diets and adoption of occidental rich animal products (van Dooren et al., 2014), inadequate consumption levels of animal products (Mora et al., 2020), urban expansion (Jiang et al., 2013), quick exhaustion of soil (Frankema, 2014) and absence of terrorism (Adelaja and George, 2019) are other causes of land expansion.

In SSA, expanding agricultural land was meant to meet food security objectives. In 1960, 15% of the agricultural land was used for crop cultivation. It rose to 22% in 2010, with the majority pertaining to livestock. Agricultural production rose in absolute terms, but mainly because growing numbers of

smallholders brought more land under cultivation (Dawson et al., 2016; Mugeru and Ojede, 2014; Otsuka and Larson, 2012).

As the population is rising, food security and hunger indicators worsen in Africa. The number of undernourished people was estimated at 217.8 million in 2014–2016 above the 175.7 million in 1990–1992 (Madzivhandila et al., in AGRA 2016). Similarly, the number of people at risk of hunger is expected to increase from about 250 million to 280 million people between 2010 and 2025 (Barrett, 2013). Statistics from the UNICEF website suggest that up to six million children will be affected by life-threatening severe acute malnutrition in West and Central Africa in 2021.

Therefore, Sub-Saharan African countries are expected to require anywhere from 0.9 to 1.35 million km² of new cropland by 2030, and will also need new land for biofuel crops, grazing pasture and industrial forestry, and also to replace land lost to degradation (Lambin and Meyfroidt, 2011; Laurance et al., 2014; UNCCD, 2017). Despite these facts, continued land area expansion for the next decades may not seem problematic (Barbier, 2020; OECD and FAO, 2016).

Agricultural land expansion followed by food production and undernourishment is paradoxical. The purpose therefore is to understand the effects of agricultural land expansion on undernourishment. Thus, understanding how the use of this abundant natural resource influences food security, structural transformation and biodiversity preservation is crucial.

The expansion of agricultural land may influence the continent's ability to deal with food production problems. Furthermore, food security makes structural transformation possible since it could propel many farmers into other sectors. However, it may also cause changes in the natural habitat of many species and biodiversity. Throughout the developing world, cultivated land area is expected to increase above 47% by 2050, with about 66% of the new land coming from the depletion of natural habitats for terrestrial species (Barbier, 2004a; Fischer and Heilig, 1997).

1.2. Problem statement and contributions

Agricultural land expansion is expected to continue rising because of low production yields in SSA. Both from the theoretical and empirical view, there are numerous contradictions about the plausible effects of agricultural land expansion on agricultural sustainability.

In a threefold perspective, this work focuses on the repercussions of agricultural land expansion in sub-Saharan countries on food security, structural change and biodiversity change: Firstly, as African countries still have high rates of undernourishment (Sachs et al., 2021), it is interesting to evaluate the effects of land expansion on the former. Secondly, from an optimistic perspective and based on

theoretical reasoning (Schultz, 1951), agricultural land expansion is expected to impact the type of structural change of sub-Saharan countries. Thirdly, sub-Saharan Africa's abundant biodiversity makes agricultural land expansion risky for species, especially terrestrial mammals, birds and amphibians.

Firstly, between 2016 and 2017, the percentage of undernourishment in SSA remained at 23%, the highest among developing regions (FAO, 2021b). Also, the absolute number of undernourished people rose from 44 million in 1990-92 to 218 million in 2014-16 (OECD and FAO, 2016). This trend of food insecurity results from low agricultural productivity, climate change (Kinda and Badolo, 2019; Kogo et al., 2021), political instability and civil strife (Barnett, 2003; Schleifer and Sun, 2020).

Literature on agricultural land expansion and food security in Africa is relatively scanty, especially from a macro perspective. Recent studies analysing the links between land expansion and food security reveal that up to 300–550 million people in developing countries could be fed by crops grown on acquired land (Rulli and D'Odorico, 2014). Land expansion for crop cultivation in the region is negatively correlated with food insecurity (Keating et al., 2014). Access to agricultural land plays a significant role in ensuring adequate nutritional attainment in both rural and urban areas (Anríquez et al., 2013). In South Asia, Mughal and Sers (2020) have shown that a 1% increase in cereal production and yield is associated with up to 0.84% decrease in undernourishment.

Nevertheless, it is not certain that agricultural land expansion reduces undernourishment, as food availability may not always lead to its access nor use (Zabala, 2018), neither in Africa (Ziem Bonye et al., 2021) nor in Mexico (Galeana-Pizaña et al., 2018). It is noteworthy that most of those studies do not consider the role of agricultural land on undernourishment in sub-Saharan Africa from a macroeconomic perspective and are mostly focused on a diversified sample of developing countries. The present study seeks to close this gap as no study sheds light on this relationship in sub-Saharan Africa.

Secondly, food insecurity in Africa can justify the large share of employments in agriculture. Indeed, until countries can enough food, labour is trapped in agriculture (Schultz, 1964; Yang and Zhu, 2013). This is comforted by two facts: almost all the actors of the agricultural sector suffer from poverty and poor yields (Barrett, 2013). These are obvious evidence that agriculture has a subsistence purpose for SSA countries, which confirms that agriculture has the highest proportion of employment.

In SSA, agricultural employment remains high, despite rapid decline. More than 60% of workers were engaged in the agricultural sector in 1991, but in 2016 up to 53% of workers are still in the sector (WDI, 2021). In addition, the reduction in agriculture shares in GDP and employment has not

been followed by an expansion of the manufacturing sector as expected (Diao et al., 2017), causing a structural change ‘bypassing’ the secondary sector (Cadot et al., 2015). The informal tertiary sector has little evidence of driving sustained growth (Mensah et al., 2018).

Therefore, increasing agricultural land can enhance structural change considered as the movements of labour force out of the agriculture sector. Recent economic literature reveals that agricultural land expansion effects are not homogeneous. Some of its advantages include that it supports long-term economic growth (Barbier, 2020; 2021). While economic growth and structural change are companions (Gabardo et al., 2017), land elasticity may explain structural transformation (Johnson and Vollrath, 2020). Conversely, agricultural land expansion could increase youths’ involvement in agriculture, making economies be more agrarian (Yeboah et al., 2019) or reducing industrial development (Rozaki, 2020). Literature is silent on the relationship between agricultural land expansion and structural change in sub-Saharan Africa, and this work intends to fill that gap.

Thirdly, species declines in SSA are due to increasing land use for agriculture. This increases loss of habitats and threatens wildlife species (Perrings and Halkos, 2015), alters tropical old-growth forests, woodlands, and semi-arid environments (Fenta et al., 2020; Laurance et al., 2014). The Millennium Ecosystem Assessment concluded that the main driver of the process is the extensive growth of agriculture, caused by population-driven demand for food, fuels and fibres in poor countries (Halisçelik and Soytas, 2019).

Many studies find that biodiversity loss has several drivers such as climate change and global warming (Newbold, 2018), ongoing expansion, emergence and integration of markets and states (Kontoleon et al., 2008), logging is the biggest threats to species on the IUCN Red List (Maxwell et al., 2016), economic growth (Iritie, 2015; Sol, 2019), infrastructure expansion (Laurance et al., 2014), institutional quality (Muchapondwa and Stage, 2015; ’t Sas-Rolfes, 2017) and community governed protected areas (Ullah and Kim, 2021) and agricultural expansion (Perrings and Halkos, 2015).

No recent study establishes the link between agricultural land expansion and fauna biodiversity loss in Sub-Saharan Africa. In this context, African countries have achieved remarkable progress in protected area designation for terrestrial and inland water areas since 2015 (UNEP-WCMC and IUCN, 2018). Although a recent study concludes that habitat change caused by land expansion threatens significantly fauna biodiversity in South and Southeast Asia (Tan, Chen, et al., 2022), closer studies show that agricultural land reduces plant biodiversity in west Africa (Balima et al., 2020) and sources animal biodiversity extinction (Perrings and Halkos, 2015). However, they use country-level approaches and ignore the temporal dimension in their analysis, which this study does using a more recent database and appropriate methodology.

In this study, the triple imperatives of agricultural sustainability which are food security, structural change and preservation of the environment or biodiversity require stepping beyond conventional and traditional conversationalist approaches. If nature conservation is essential (Dasgupta, 2021), particularly in certain very sensitive areas in terms of biodiversity such as the ‘hot spots’ of sub-Saharan Africa, it cannot, however, constitute a credible response on the scale of tens of millions of hectares which represent considerable socio-economic challenges (Gartlan, 1989).

Policies and governments are called upon to undertake measures so that the extensive growth of agricultural land ties with the objective of food security, fits into the objective of virtuous structural change and aligns with the restriction of biodiversity loss in sub-Saharan Africa. Analysing the effects of agricultural land expansion is crucial to formulating appropriate policies at the national and continental levels.

Therefore, the central question of this study is: **What are the effects of agricultural land expansion on agricultural sustainability in sub-Saharan African countries?**

This main question is subdivided into three secondary questions:

1. What are the effects of agricultural land expansion on food security?
2. What are the effects of increased agricultural land on structural change?
3. What effects does agricultural land expansion have on biodiversity change in sub-Saharan Africa?

1.3. Objectives

The main objective of this thesis is to analyse the effects of agricultural land expansion on agricultural sustainability in sub-Saharan African countries. More specifically, it unfolds as follows:

1. To measure the effect of agricultural land expansion on food security
2. To evaluate the effect of agricultural land expansion on the type of structural change.
3. To assess the contribution of agricultural land expansion to biodiversity change.

1.4. Hypotheses

The study has the following research hypotheses:

1. Agricultural land expansion reduces the prevalence of undernourishment.
2. Increased agricultural land raises the probability for countries to have industrial type rather than service type of structural change.
3. Agricultural land expansion increases the number of threatened mammal species in sub-Saharan Africa.

1.5. Interest of the study

The present study has three contributions to the existing literature. Each contribution is tied to a specific research question which is exposed in the problem statement section. The first contribution of this thesis is heuristic as it identifies how agricultural land expansion relates to undernourishment alleviation in sub-Saharan Africa. Mughal and Sers (2020), support that expanding land does not guarantee food availability, nor access nor use. At the end, this essay verifies whether increasing land for agriculture purposes is efficient in reducing undernourishment prevalence.

This thesis's second main contribution is to identify the type of structural change agricultural land expansion causes in sub-Saharan Africa. Although abundant, all recent studies fail to analyse land expansion as a determinant of the type of structural change, except Mensah et al. (2016). The methodology contribution is based on the use of a pooled multinomial logit. This model allows identifying which type of structural change is more likely to be created by agricultural land expansion in sub-Saharan Africa.

Thirdly, this thesis implements a short panel that accounts for temporal dimension. Similar studies (Tan, Chen, et al., 2022; Tan, Yiew, et al., 2022) focus on the Asia and South Asia context however. This methodology approach is different from studies using theoretical analysis ('t Sas-Rolfes, 2017; Muchapondwa and Stage, 2015; Iritié, 2015), calibration techniques, simulations and scenarios (Chaplin-Kramer et al., 2015; Molotoks et al., 2021; Zabel et al., 2019) satellite imagery, map descriptions and analyses (Fitzherbert et al., 2008; Gaveau et al., 2016; Gibbs et al., 2010; Kraemer et al., 2015; Laurance et al., 2014; Phalan et al., 2013; Zeng et al., 2018) non-causal or descriptive analyses (Lawrence et al., 2014; Medan et al., 2011); econometric causal analyses for country-level studies (Perrings and Halkos, 2015; Sol, 2018) and only long panel analysis (Ullah and Kim, 2021). According to this review, the temporal dimension is ignored in studies linking agricultural land expansion and biodiversity loss in Africa.

1.6. Organisation of the thesis

This thesis assesses the effects of agricultural land expansion in sub-Saharan Africa on three wedges of sustainable agriculture: social, economic and environmental. The first essay analyses the consequences of agricultural land expansion on food security. The second essay investigates the type of structural change that agricultural land expansion dictates. The third essay analyses the effects of agricultural land expansion on biodiversity in sub-Saharan Africa. The essays are framed by a general introduction and conclusion.

ESSAY I
FOOD SECURITY EFFECTS OF AGRICULTURAL LAND EXPANSION IN SUB-SAHARAN AFRICA

This essay is published as a working paper available using this link <https://doi.org/10.31235/osf.io/2djpe>

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1. Introduction

Despite national and international efforts to reduce poverty, the number of people suffering from chronic hunger increased by 821 million, and are mostly found in Africa and South America (FAO, 2018b). In sub-Saharan Africa, one in four people suffered from chronic food deprivation in 2017. The prevalence of undernourishment has increased, from 22.7% in 2016 to 23.4% in 2017. The number of severe food-insecure people in Central Africa rose from 50.6 million in 2005 to 79.6 million in 2017 (FAO, 2019).

Agricultural land expansion is expected to play an important role in mitigating this high priority goal of nourishment. To meet current food demand, it is estimated that more than one third of the land area is used as cropland or pasture (FAO, 2018b; Mora et al., 2020). Rapid population growth coupled with increased food demand, requires either expansion of agricultural land or sufficient production gains from current resources (Fitton et al., 2019; Ricardo, 1817).

Although estimates of additional arable land vary, Alexandratos and Bruinsma (2012) report up to 1.4 billion ha of good or prime land that could be brought under cultivation if needed. However, this is with some loss of pastures and significant infrastructure investment. Lambin et al., (2013) suggest that much lower areas of land are suitable for expansion of arable agriculture when all constraints are considered.

However, there are great controversies in the literature concerning the food security effects of agricultural land expansion. Some studies find that land expansion is principally at the benefit of food security (Busch and Ferretti-Gallon, 2017; Carrasco et al., 2017; Lambin and Meyfroidt, 2011; Laurance et al., 2014; Meyfroidt, 2018; Meyfroidt et al., 2014). Meanwhile, other studies find that agricultural land expansion has not led to food security improvements (Mechiche-Alami et al., 2021; Zabala, 2021; Galeana-Pizaña et al., 2018;), or can exacerbate social disharmony and food insecurity through violence and conflicts (Mechiche-Alami et al., 2021; Sauer, 2018). Most of these studies use simulations and landscape analysis, but not econometric techniques. Furthermore, the links between agricultural land expansion and food security are not yet clearly established in sub-Saharan Africa. This essay examines the effect of agricultural land expansion on undernourishment alleviation in sub-Saharan Africa.

This essay is organised as follows. Section 2 contains the stylised facts of food security in sub-Saharan Africa; Section 3 presents the literature review; Section 4 exposes the methodology; Section 5 presents results and discussion and Section 6, the conclusion.

2. Stylised facts on the state of food security in sub-Saharan Africa

Despite global commitment and efforts to improve undernourishment, 821 million people (about 9% of the world's population) remain undernourished, of whom 250 million (36%) live in Africa (FAO, 2018a; Foley et al., 2011). Looking ahead, food security remains high on the agenda of the Sustainable Development Goals (SDGs) with a new target of 'zero hunger' by 2030 (Porter et al., 2014). Achieving this target is a challenge given the need to feed more people from the projected increase in the world's population (Sachs et al., 2021).

This section analyses food security trends in sub-Saharan Africa, focusing on undernourishment. The prevalence of undernourishment is the traditional indicator of the access dimension of food security. This indicator is derived from official country data on food supply, food consumption and energy needs, while taking into consideration demographic characteristics such as age, sex and levels of physical activity (FAO, 2021a).

However, two other types of comprehensive indicators represent the access dimension of food security. First, moderate food insecurity describes the situation in which people face uncertainties about their ability to obtain food and have been forced to reduce the quality and/or quantity of food they consume at certain times of the year due to lack of money or other resources. Second, severe food insecurity occurs when people are likely to have run out of food, experienced hunger and, in extreme cases, gone several days without food, putting their health and well-being at serious risk (FAO et al., 2020).

Undernourishment occurs when food security is not guaranteed, due to a gap in one or more of the three pillars. In 2015, about 793 million people (10.9% of the world's population) were predominantly undernourished (FAO et al., 2015). Thus, even if enough food to feed the Earth's population is available, undernourishment can occur when access and use are not met locally (Abbade and Dewes, 2015; Holt-Giménez et al., 2012).

However, if the use of natural resources such as land for agriculture increases, it can lead to a quantitative increase in production in absolute terms (for all crops) as well as in relative terms (for a given crop). This will improve food stability.

This section presents the evolution of undernourishment in sub-Saharan Africa, compares some countries and illustrates food security by using other indicators.

2.1. Evolution of undernourishment in Sub-Saharan Africa

Figure 3 shows trends in undernourishment in Africa region and the world, on the one hand, and the number of undernourished in Africa on the other. The available data allow analysis from 2000 to 2020, with 2020 being the projection. The first important point is that, similarly to other regions of the world, between 2000 and 2017, the share of undernourishment prevalence in Africa has decreased from 27% to 22%.

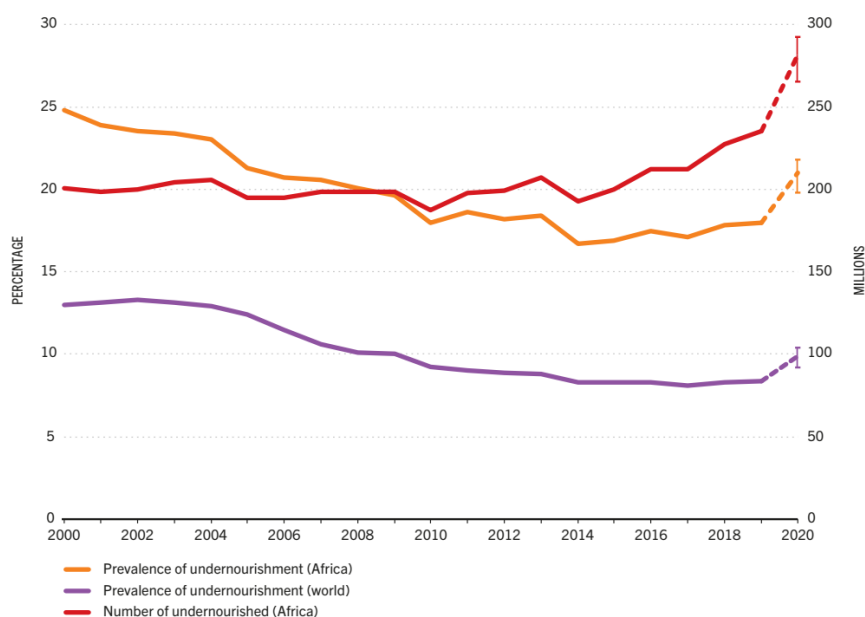


Figure 3: Prevalence of undernourished people in the world and Africa, and the number of undernourished in Africa.
Source: FAO et al. (2021)

Notes: Values for 2020 are estimates. The bars indicate the range for the 2020 estimates.

However, a deeper look at the figures reveals that the prevalence of undernourishment has deteriorated significantly since 2014. In 2020, 21% of the population was undernourished, an increase of 4.3 percentage points since 2014. About 70% of the increase in the undernourishment prevalence between 2014 and 2020 occurred in the period from 2019 to 2020.

Due to these figures, Sub-Saharan Africa remains the region with the highest proportion of undernourished people in the world. Its probability of achieving the goal of ‘zero hunger’ by 2030 is in question. Moreover, the forecasted population growth, global warming and climatic conditions, as well as the negative impacts of the COVID-19 pandemic, call for the unwanted possibility that the number of undernourished people could climb from 83 to 132 million by the end of 2020 (FAO et al., 2020).

In 2020, 281.6 million Africans were undernourished, an increase of 89.1 million since 2014. There is significant variation in the levels and trends of hunger across the subregions. Of the total number

of undernourished, 44.4% or 125.1 million people live in Eastern Africa, 26.7% (75.2 million) in Western Africa, 20.3% (57.1 million) in Central Africa, 6.2% (17.4 million) in Northern Africa and 2.4% (6.8 million) in Southern Africa. Africa accounts for 55% of the global rise in the number of undernourished over the 2014 to 2020 period. In addition, Eastern and Western Africa account for 83% of the Africa-wide increase over the 2014 to 2020 period (FAO, 2021a).

2.2. Prevalence of undernourishment in some countries

Analysis of the evolution of undernourishment prevalence in Sub-Saharan African countries (figure 4) shows a generally decreasing trend over time. Thus, based on this indicator, food security in sub-Saharan countries is improving. Two countries whose prevalence of undernourishment was above 45%, have in almost two decades seen this rate drop to around 20%.

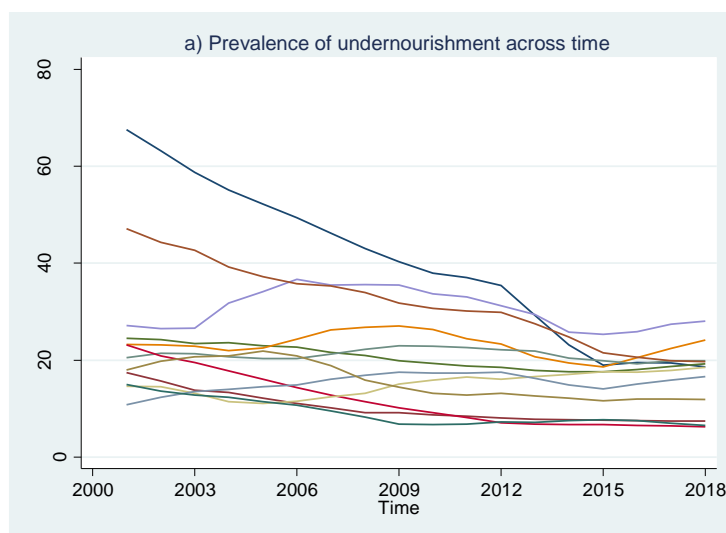


Figure 4: Evolution of the Prevalence of undernourishment, for countries
Source: Author

For the rest of the countries, there are particularities where undernourishment is increasing. However, it should be noted that in other countries, the prevalence rate halved from 20 to 10% between 2001 and 2018. The study's basic assumption is that this improvement is a response to an increase in agricultural land area. It is mainly due to the availability of arable land and improved access to irrigation which has enabled greater production of food. Additionally, government initiatives such as subsidies and other financial incentives also helped to increase agricultural production.

2.3. Prevalence of moderate or severe food insecurity in the population

FAO introduced the prevalence of severe food insecurity in 2017. The indicator is based on the Food Insecurity Experience Scale (FIES) as a complementary indicator of hunger to FAO's traditional

indicator, the prevalence of undernourishment, to provide additional information on the access dimension of food security.

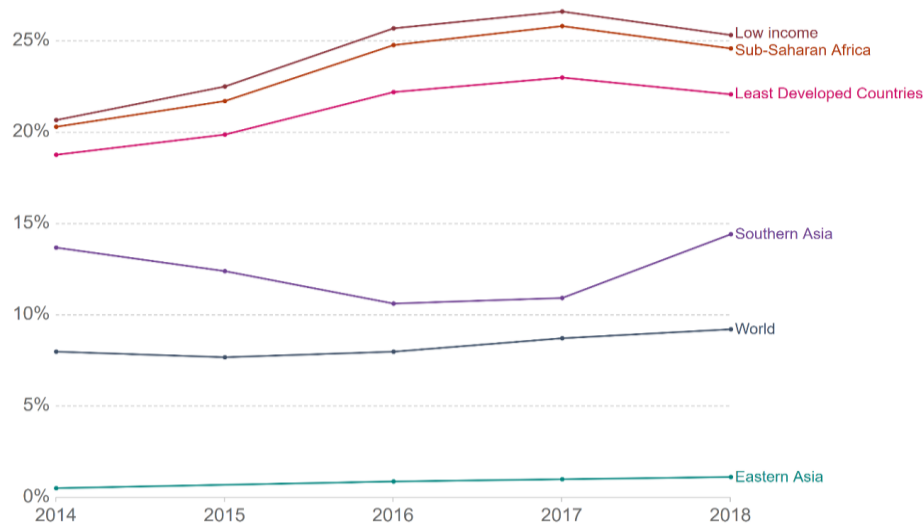


Figure 5: Share of population in moderate or severe food insecurity
Source: FAO

The upward trend in undernourishment over the 2014 to 2018 period in Africa is confirmed by the rise in the prevalence of moderate or severe food insecurity within the population (figure 5). This trend was particularly noticeable in Southern Africa, which may have reflected the severe economic conditions in South Africa in 2016 and 2017. In all subregions, severe food insecurity appears to have fallen from 2017 to 2018, even if only marginally in some cases. The improvement was strongest in Eastern and Northern Africa.

However, moderate food insecurity has worsened or remained unchanged in Western and Southern Africa. The measure of moderate or severe food insecurity also shows that in addition to the 277 million people in Africa who are severely food insecure, there are 399 million people who are moderately food insecure, i.e. they did not have regular access to nutritious and sufficient food, even if they were not necessarily suffering from hunger. Of these, 87 percent live in sub-Saharan Africa.

3. Literature review of agricultural land expansion and food security nexus

This section makes a presentation of the theoretical background and the empirical literature, linking agricultural land expansion and food security.

3.1. Agricultural land expansion and food security: Theoretical background

Numerous approaches explain how expansion of agricultural land area can explain food security. The theories can be subcategorised into three approaches: the productivity approach, the ends approach and the demographic density approach.

3.1.1. Agricultural land expansion and food security: a productivity approach

There is non-consensual debate on the returns of agricultural land and its ability to sustain food security. In economic theories, the ability of agricultural land to advocate food security is subject to authors' views of productivity of agricultural land. Increasing or diminishing returns of agricultural land affects food security differently.

3.1.1.1. The physiocracy and the surplus of agriculture

The physiocrats were the precursors of political economy and, like Xenophon, based all achievements on agriculture. The leader of this school of thought, Quesnay, believed that wealth came from the primitive goods of land, men and livestock (Béraud and Faccarello, 1992). For the physiocrats, appropriating land was synonymous with food abundance. Indeed, they supported the idea that extensive agricultural growth would produce a quantity of product greater than the community's food needs. Thus, the expansion of agricultural land is central to the creation of wealth and therefore a source of well-being for the population, and the availability of a variety of foods (Cantillon, 1755). The agricultural sector creates subsistence goods for consumption by the population, which improves the nutritional status of the population. To fight hunger and an unequal diet, they advocate the increase of agricultural land so that the surplus can be transformed into luxury goods (Quesnay, 1758). The more land that is cultivated, the greater the agricultural surplus that is available to ensure the food security of the population.

Similarly, from the analysis of Adam Smith's view point, land for agriculture is subject to increasing returns (A. Smith, 1776). Had it been expanded agricultural land would have produced more and more output. The agricultural output is ready for farmers' consumption or the community through markets and trade. The trade guarantees an equitable access to wealth of the nation, and makes all commodities affordable to all citizens, because prices are all flexible. This traded output could not only increase the availability of varied food stuffs, but also improve the quality of living standard of the population and raise the wealth of the nation. Here, food security cannot be threatened either in the short or the long run, unless there are no cultivable lands to bring into cultivation.

3.1.1.2. The classicalist returns of agricultural land expansion: the debate

Contrarily, next considerations to diminishing returns seen by others (Marshall, 1890; Ricardo, 1817) question the real power of agricultural land to guarantee food security. Indeed, the Ricardian diminishing returns' theory holds that land has different fertility statuses. In absence of technology, the increase in land results in very short-lived increase of agricultural production. The use of land will be followed by decreasing returns and decreasing agricultural output. More land will be necessary to ensure food security of the nation while causing agricultural expansion. Extensive agriculture will yield lower and lower agricultural product. However, because of a steadily growing population and decreasing returns of land as well, food security could not be solved for a long period of time.

Another interesting view concerns Marshall (1890) conception of diminishing returns with respect to time. The diminishing returns tendency operates if the time element is eliminated, if the quantity of land is assumed fixed, and if constructive ideas are not developed in technique or organisation. In his *Principles of Economics*, he claims that diminishing returns runs as follows: '*An increase in the capital and labour applied in the cultivation of land causes in general a less than proportionate increase in the amount of produce raised, unless it happens to coincide with improvements in the arts of agriculture.*' This means that, if there is a possibility to increase agricultural land, diminishing returns will not operate, and agricultural produce will increase enough to solve food insecurity.

Therefore, there is no unanimous perception about the ability of agricultural land expansion to alleviate food insecurity, because conceptions of returns of agricultural land do differ. This essay seeks to shed light on how increase in cultivated areas is linked to the problem of food insecurity.

3.1.2. Agricultural land expansion and food security: the ends approach

According to the ends approaches, agricultural land expansion has many ends such as for biofuel production, commercial agriculture and food security of foreign countries. Therefore, expanding agricultural land may have diversified effects on food security.

3.1.2.1. Debate over the ethics of industrial and biofuel production against food crop production

While it is acknowledged that increasing land can reduce food security in the early stages of development, chances are great that land expansion reduces food availability as countries modernise.

Linking expansion of industrial crop production and food security various outcomes can lead to diversified outcomes. Indeed, food security has emerged as one of the most extensively studied impacts (Jarzebski, Ahmed, Boafo, et al., 2020), largely due to the rapid expansion of biofuel projects during the recent land rush, and the popularity of negative narratives such as land grabbing, land

dispossession and ‘food vs. fuel’. Many studies have explored the food security outcomes of industrial crop production in SSA across different scales, from the household level to the national and international level (Jarzebski, Ahmed, Karanja, et al., 2020; Negash and Swinnen, 2013; Zeller and Sharma, 2000). The perceptions and outcomes of industrial crops articulated in these studies are very polarised, ranging from ‘industrial crops as major risks to food security’ (Jarzebski, Ahmed, Boafo, et al., 2020; Wiggins et al., 2015) to ‘important agents of economic growth and rural transformation’ whose expansion could have positive food security outcomes (Arndt et al., 2008, 2011; Hartley et al., 2019; HLPE⁴, 2013).

However, Schiffman (2013) holds that biofuel production threatens the survival of local communities and exacerbates their starvation statuses. He identifies biofuels as a factor contributing to local food shortages in some areas. This is because it involves the shift from growing food crops to the production of biofuels – mostly for export – in regions of Africa, Asia, and Latin America. Palm oil, jatropha, and sugar cane are being grown in the Philippines, Indonesia, Guinea, and elsewhere to feed Europe’s (and to a lesser extent the United States’) appetite for a cheap and sustainable replacement for gasoline. But in places like Sumatra – where Asia’s last great rainforest is being razed to make way for massive palm oil plantations – the current biofuels boom is anything but sustainable. Nor is it sustainable for the Guarani of Brazil, who is fighting a losing battle to maintain their tribal lands against the U.S. food giant Bunge, which is buying great tracts to produce ethanol from sugar cane.

Goklany (2011) estimates that the increase in biofuel production may be responsible for as many as 200,000 deaths per year from hunger and hunger-related illnesses. He argues that this massive shift in land use has decreased the amount of food available for human consumption, and consequently raised the prices of vital staples. There are now millions who can no longer afford to buy these staples in sufficient quantities. He further says that agricultural area expansion effects on food security mostly depend on the nature of the product cultivated in the farm. When, staple crops or foodstuff crops are grown on the new expanded lands, it helps to reduce food insecurity. However, when agricultural land areas are dedicated to biofuel production it fosters food insecurity and hunger.

3.1.2.2. Agricultural land expansion and food security: Comparing large-scale monoculture versus small scale intercropping

Generally, large-scale farms are specialised in a single-crop culture while the small-scale farmers grow more than 2 or 3 crops simultaneously in the same farm. Economists tend to use ‘yield’ measurements when calculating the productivity of farms. Yields can be defined as the production

⁴ HLPE means High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

per unit of a single crop. For example, beans farm will be judged by how many metric tons of beans are produced per hectare. It is true that the highest yield of a single crop is often achieved through industrial monocultures, and smaller farms can rarely compete with this monoculture single-crop yield (Kimbrell, 2003).

The large-scale plantation exacerbates food insecurity. Agricultural land acquisitions by large-scale farms support agriculture for exports. According to Olivier de Schutter, '*Small-scale family agriculture, on which most of the world's rural poor still depend, is threatened by large-scale plantations, export-led agriculture, and the production not of food but commodities.*' (Borras et al., 2011). The consequences of this process have been profound, and have threatened millions with starvation.

However, because small-scale farms use 'intercropping' methods to plant other crops where single-crop monocultures have empty 'weed spaces', and because small farmers are more likely to rotate or combine crops and livestock with the resulting manure replenishing soil fertility, these small-scale integrated farms produce far more per unit area than large farms. Though the yield per unit area of one crop – corn, for example – may be lower on small-scale farms, the total output per unit area (with small farms often producing more than a dozen crops and numerous animal products) is nearly always higher than that of larger farms (Kimbrell 2003).

This means that cultivated area expansion by small farmers offers at least two ways of solving food insecurity from both the availability and diversity of food. The latter dimension is not as much taken into account when expansion of agricultural areas benefits to large-scale farms for monoculture. Therefore, if land expansion for agriculture is initiated by local producers, as assumed in this essay, it can foster food security.

3.1.2.3. Agricultural land expansion through grabbing and food security

The expansion of agricultural land can be caused by large-scale acquisitions and supported by foreign developed countries. This is termed as land grabbing and mostly has the aim of ensuring home food security than host food security. 'Land grabbing' is known as to the purchase or long-term lease of vast tracts of land from mostly poor, developing countries by wealthier, food-insecure nations as well as private entities to produce food for export. This concept is becoming gradually important since 2008, and raised deep concern over food security. Land grab represents a major shift from public to private sector control over agricultural investment, and from domestic to foreign control over crucial food-producing lands. Mechiche-Alami et al. (2021) concludes that it does not always lead to food security as land owners (foreign countries) either produce cash crops or food crops but for their population food security.

Because of the establishment of large farms through land grabbing, numerous are former small farmers who have been pushed off their land by a variety of economic forces. According to Olivier de Schutter, the UN Special Rapporteur on the Right to Food, ‘Small-scale family agriculture, on which most of the world’s rural poor still depend, is threatened by large-scale plantations, export-led agriculture, and the production not cash crops.’ The consequences of this process have been profound, and have threatened millions with starvation (Daniel, 2011).

In the same vein, it is argued that the spread of large-scale industrial agriculture in Africa and across the global South will ultimately lower food costs and benefit the poor. But surprisingly, recent price increases call this view into question (Schiffman, 2013). When local food prices levelled at highly unstable global commodity prices, it is often the people at the bottom of the economic ladder who are the first to suffer the pain. The poor, many of whom already spend more than half their income on food, can still afford to pay more for staple goods. This worsens food insecurity (Schiffman, 2013).

3.1.3. Agricultural land expansion and food security: a demographic density approach

The food security effects of agricultural land expansion are subject to population density specificities. Increased cultivated land area accounts for a significant portion of production increase which shrinks the level of food insecurity in the early stages of modernisation. Two divergent trends propose explanations: many small but widespread additions in already high population density areas; and, occasionally, large tracts of underutilised land in low population density areas.

3.1.3.1. Additions in high population density areas

Densely populated rural areas have low probability of possessing idle agricultural land, and can make good use of available technology. Subsequently, converting more land to agriculture augments agricultural output. As matter of fact, in highly populated Ethiopia, for more than 20 years, increased land accounted for about 40 percent of the rapid agricultural growth, while India experienced increasing returns as well (Mellor, 2017). Based on the Ethiopian and Indian experience, Mellor (2017) argues that ‘the logic is clear. Technological change brings increased returns to land, covering the costs of bringing additional land into cultivation.’ Although land is limited, increased land areas supported by technological change is expected to improve availability of food and its use to curb food insecurity.

3.1.3.2. Additions in low population density areas

The situation in the low population density areas is merely different to that of high densely populated areas. Those areas are commonly dry and inhabited sparsely by semi-nomadic families, and where land use is restricted by disease. Generally, cultivable areas there could have high potential

productivity, but may require substantial investments in roads and irrigation systems, although developing it may be highly profitable (Laurance et al., 2017).

There are two major issues about investing and developing such lands. First is the issue of who will make the infrastructure investment and this should be considered in view of the investment made by those who will farm the land. That decision in the context of small commercial farm areas has the potential of large increases in productivity that will hasten food security.

Second, is the irrigation issue. Irrigation increases land areas to be cultivated (Mellor, 2017). Returns from investment in irrigation are likely to be higher in existing areas that could benefit from an additional crop and ensuring production in the main cropping season, often with lower-cost water sources. Vast areas of Asia (e.g. in India and Pakistan) have been irrigated, long before modern yield-increasing technologies were on the horizon. Presumably, that investment paid off, at least where the underlying resource was dry (Mellor, 2017). Hence, expanding land in underpopulated areas can help to cure food insecurity if backed by irrigation. However, it depends on whether that land will be dedicated to food crops or biofuel.

This subsection has enabled us to show that they are different approaches in theoretical economic review relating agricultural land expansion to food security. It has been shown that within each of the approaches, many strands are conflicting one to the other. Therefore, the theoretical debate justifies the necessity to shed lights on the relationship between land expansion for agriculture and food security. More evidences are given with empirical studies in the next subsection.

3.2. Agricultural land expansion and food security: Empirical review

Although empirical literature on this topic is scanty, this subsection provides the restitution of empirical studies linking on one hand, agricultural land expansion and food security, and, on the other hand, studies relating other aspects of land and food security.

3.2.1. Agricultural land expansion and food security

3.2.1.1. Expanding land for agriculture

Ngoma et al. (2021) use national representative data and tobit model to conclude after their research that cropland expansion by smallholders into forests represents about 60% of the estimated 250,000 ha of forests lost per year in Zambia. Most households expanded cropland because they needed to meet subsistence food requirements and a few others in response to market opportunities. This goes in line with the findings of Keating et al. (2014). Using arable land as control variable, and find that in developing countries, expanding land significantly increases food availability and further reduces the rate of undernourished people.

Likewise, in India Kumar and Sharma (2020) investigate if agricultural expansion by restoring the degraded lands provokes food security in India. They use descriptive statistics and conclude that reclamation of 2.18 million ha of salt-affected soils has contributed more than 17 million tons of food grains per annum to the country's food basket, with additional annual income of Rs. 15.5 billion. Moreover, other technologies of management of salt-affected soils, have positively impacted food and nutritional security. On this basis, expansion of agriculture in sub-Saharan African countries, through the restoring degraded land, can also increase the food security indicators.

Then, Anriquez et al. (2013) proves at the micro level and using partial equilibrium approach and micro-simulations that access to agricultural land ensures food security taking nutritional attainments, as a measure of welfare. As secondary result, they discovered that access to agricultural land plays a significant role in ensuring adequate nutritional attainments in rural areas, and even in urban areas.

Then neatly, in their historical study, Ramankutty and Foley (1999) drew maps disclosing the positive evolution of cropland area from 1700 to 1992, showing both the spread of cropland and its intensification in all regions. Before 1900, agricultural expansion was the most prominent way to increase food production, as with food grain production during 1949–65 in India (Narain, 1977; Vaidyanathan, 1986). But after the advent of industrial agriculture, using revolutionary cultivation techniques could also increase productivity on the same land.

Conversely, Wise (2021) taking the case of Rwanda and Zambia, concludes that productivity does not increase overall production as extensification does. He uses a twofold decomposition methodology and find that production results more from agricultural land use than from intensification. This is in line with estimations of FAOSTAT (2013), which over the period 1961 to 2000 in Africa, the land footprint grew by only 11%, while agricultural output grew by 153%.

On the other hand, some studies on extensification of agricultural frontier can find mitigated links with food (in) security, because of impoverishment of lands, land disputes or food wastage. Zabala (2021) uses pure narrative and Galeana-Pizaña et al. (2018) use cartography and spatial estimations methodologies to show that increases in agricultural land cover have not led to improvements in food security in Mexico for almost four decades, except for the case of corn self-sufficiency. The trends of agricultural expansion in three ecoregions were related to increases in food production. However, livestock expansion, a land-use change also common in other regions in Latin America, was associated with diminishing food security in most ecoregions.

Analysing graphs of chronological data on food security, Ramankutty et al. (2018) find that despite the calorie production per capita due to agricultural land expansion, malnutrition still persists in 158

countries. Despite of using mapping and Landsat, Sauer (2018) draws similar conclusions, saying that agricultural modernisation and the expansion of the agricultural frontier, contributed to the emergence of new territorial disputes, creating additional obstacles and increasing the demand for land prices of land, increasing thus food insecurity in Pará's State in the Brazilian Amazon. The result is supported by Godfray et al. (2010) in his descriptive analysis. Findings suggest that output of food-producing lands should be more helpful against undernourishment if wastage were avoided. In the developing world, losses are mainly attributable to the absence of food-chain infrastructure and the lack of knowledge or investment in storage technologies on the farm. So, reducing wastage at relevant levels will optimise the food-producing lands' capacity to cure undernourishment.

However, the previous studies (except Kinda and Badolo, 2019; Godfray et al. 2010) analyse food security in terms of food production or availability. If the latter study is old, the more recent consider all developing countries. Although nutritional status is more crucial to cease food security (Rulli and d'Odorico, 2014), this essay is more attached to agricultural land expansion effects on social dimension of agricultural sustainability in sub-Saharan Africa.

Access to land is an important driver of land expansion. Muraoka et al. (2018) explore the link between access to land and food security. Land rental is found to be the main approach used by rural households in a given year to access additional land for cultivation. Econometric results of his frictional model indicate that land rental markets in Kenya do not allow for the reallocation of land in a way that would fully contribute to national food security and poverty reduction objectives. Though, with imperfections of land rental markets, land rental still contributes to rural household food security. Equally, van Wijk et al. (2019) with graphical and correlation analysis conclude that access to land can have damages on the food security of small holders in SSA. Indeed, they find that the link between food security and farm size in smallholder households is relatively weak and they further add that although unequal access to land translates into unequal food security.

Another interesting link concerns the agricultural production and nutritional status relationship. They are two contradictory strands of studies. To kick off, Mughal and Sers (2020) with an econometric model on macroeconomic data examine the role played by the increase in cereal production in improving the South Asia region's nutrition and food security. Estimates from the Generalised Method of Moments Findings suggest that a 1% increase in cereal production and yield is associated with up to 0.84% decrease in the prevalence of undernourishment significant over a period of 3 years. Ray (2007) investigates the changes in the nature and quantity of food consumption in India during the reform decade of the 1990s, and analyses their implications for calorie intake and

undernourishment. The author concludes that an increase in quantity of food consumed will reduce the ratio of people suffering from undernourishment.

However, Purwestri et al. (2017) analyse the paradox between high rice productivity and low nutritional status of children triggered in the Demak Regency and the prevalence of stunting of children under five. Using Independent T-test and MannWhitney U-test to conclude that, even though the area has high rice production, child malnutrition, was still high. Similarly, it is found uncertain that agricultural expansion reduces undernourishment, as the availability of food may not always lead to its access nor use (Zabala, 2021) in Africa (Ziem Bonye et al., 2021) or in Mexico (Galeana-Pizana et al., 2018).

However, none of these studies consider the role of agricultural land on prevalence of undernourishment, except Anriquez et al. (2013), whose study does not explore food security at national levels, to draw their conclusions, as the study dares to do. Moreover, few studies use econometric tools on macro data to assess the relationship between agricultural land expansion an food security.

3.2.1.2. Land expansion backed by large scale land acquisition

Several studies interested in land expansion from land acquisition and food security do not end up to a consensual result. Firstly, land acquisition has the real potential to alleviate food insecurity. As a matter of fact, Daniel (2011) in his theoretical paper, investigates with his narrative methodology under which conditions land grabbing in developing country land markets impacts land reform agendas and other policies to promote food security. Estimating the potential yield with land matrix data base, Rulli and d’Odorico (2014) analyse the effect of large-scale land acquisitions on food availability in developing countries and find that up to 300–550 million people could be fed by crops grown in the acquired land.

Secondly, several studies conclude that land grabbing has negative impacts on food security. For instance, Mechiche-Alami et al. (2021) apply mapping and simulations to conclude that Large-Scale Land Acquisitions (LSLA) in Africa meet identified food security needs only in a minority of countries. They find that the most productive land is most often allocated to flexible crops, while food crops are produced on more marginal land. Therefore, showing that even when their objective is agricultural production, most LSLA are unlikely to improve food security. Similarly, merging agricultural, remote sensing, and plot-level survey data of 11 African countries, georeferenced information on 160 land acquisitions in 39 countries, Müller et al. (2021) find that land expansion associated backed by land acquisition causes food security as energetic crops are cultivated at the expense of nutrient crops. Moreover, it is proved with mapping methodology that land grabbing

exacerbates food insecurity, decreases job opportunities, sparks migration in host country (Nyantakyi-Frimpong and Bezner Kerr, 2017), increase social conflicts between farmers and pastoralists (Oberlack et al., 2016; Soeters et al., 2017). In northern Sierra Leone, Yengoh and Armah (2015) use a mixture of quantitative and qualitative research methods with group comparisons of a program to conclude that expansion of land acquisition causes an increase in the severity of food insecurity and hunger.

Also, wages from employment by the company cannot meet the staple food needs of its employees. Furthermore, the results of Marselis et al. (2017), using computable general equilibrium model suggest that land acquisitions reduce the local availability of agricultural land per capita and could potentially affect local food security. Ahrends et al. (2015) mobilises mapping and principal component analysis to evaluate the spread of rubber between 2005 and 2010 in combination with environmental data. They conclude that expansion of monoculture rubber plantations into marginal areas creates a clear potential for loss-loss scenarios, such as the clearing of high-biodiversity value land for a crop that is poorly adapted to local conditions and, by altering landscape function while not producing long-term sustainable yields, may ultimately also compromise livelihoods.

Thirdly, a bunch of studies identify multiple relations between extensification through land acquisition and food security, depending on whether the dimension of food security or the type of country involved in the acquisition process. For instance, studying various regions of the world, Müller et al. (2021) that, controversially, land acquisition increases food production and exacerbates food insecurity. Indeed, agricultural land expansion from deals in these regions also shifts production away from local staples and coincides with a gradually decreasing dietary diversity among the surveyed households in sub-Saharan Africa.

In addition, Santangelo (2018) uses data on 65 developing countries from 2001-2011 and mediation analysis in his investigation. Findings suggest a differential impact depending on the investor's country of origin. When foreign investments in land come from developed-country investors, it causes a positive influence on food security by expanding land used for crop production as the but when it comes from developing country investors, it carries negative influence on food security by decreasing.

The previously cited studies focus only on land acquisition by foreigners with areas at least larger than 8 Ha (Mechiche-Alami et al., 2021). The purpose of this essay is to account the effects of the global phenomenon of land expansion on people's food security. Secondly, those studies use simulations and Input – Output methods of estimation, while this essay uses econometric techniques of estimation.

3.2.2. Land and agricultural reforms, tenure, rights and food security

The main purpose of Ceddia et al. (2019) is to assess how different land tenure regimes can direct the gains in agricultural productivity towards land sparing or Jevons paradox in ten Latin America countries from 1990-2010. The results of the dynamic panel approach confirm that agricultural expansion is indeed a dynamic process, which is characterised by temporal lags (Richards et al., 2014), and that improvements in agricultural productivity per se are land-sparing, and more importantly, the overall effect of increased productivity crucially depends on the institutional context.

Schoonbeck et al. (2013) conduct a systematic review which aims at reviewing the main potentials and challenges of organic agriculture approach when dealing with ‘undernourishment’ as a multifaceted concept in developing countries. It concludes that conventional and biotechnological approaches still produce higher yields than organic agriculture. However, considering the many advantages of organic agriculture, it can in a long run, be more conducive than now to meet food security. Implementation of organic agriculture calls for agricultural land expansion, to curb undernourishment.

Using a farm-level data from the 2005 Albania Living Standards Measurement Survey, Deininger et al. (2012) find no support for the argument that land fragmentation reduces productivity, nor does not worsen food availability. Moreover, Caian et al. (2018) investigate in the same country land fragmentation’s implications. It appears that the land fragmentation contributed to food security improvement by increasing the variety of on-farm produced foods for household self-consumption, thus ensuring a higher likelihood of meeting nutrient requirements that can promote good health of rural population in Albania.

Rao (2006) examines the conceptual linkages between the issue of land rights for women, with household food security. The author uses a narrative methodology and argues that in a context of diversified rural livelihoods, the contribution of agricultural production to household subsistence has been declining. However, the renewed production and food security nexus in agricultural policy have meant allowing men not to have responsibility for household food security. Whereas a right to land for women often left behind for agriculture management, appears to be leading to an enhancement of work burdens and food security improvement.

4. Methodology of analysis of the effects agricultural expansion on food security

In this section of the study, the methodology to assess the effects of agricultural land expansion on food security in sub-Saharan Africa is presented. The starting point is data description, followed by the estimation strategy presentation.

4.1. Description of data and variables

This subsection provides more information on the data and scope of the study, the building and explanation of variables in the model, and the tools used to describe the links and stationarity tests.

4.1.1. Nature, data sources and scope of the study

In this essay, all the data are quantitative, from secondary sources and rely on the World Bank's World Development Indicators (WDI, 2021). The data on food security are from the Food and Agriculture Organization of the United Nations (FAO, 2020) and the variables on governance and institutions are from the World Governance Indicator (WGI, 2021). The study considers 28 countries in Sub-Saharan Africa, over the period 2000–2016. Both temporal scope and number of countries are based on data availability.

4.1.2. Description and construction of variables

4.1.2.1. Measures of food security

Because of the multidimensional aspect of food security, several indicators have been used in the literature. They are subcategorised in simple and composite indicators.

a. Simple indicators of food security

Four dimensions of food security exist: availability, access, utilisation and stability. Several variables can capture each of these different dimensions. Availability is measured by production or livestock index, or by average dietary energy supply adequacy (Caccavale and Giuffrida, 2020; Mechiche-Alami et al., 2021) accessibility pillar is captured by the per capita GDP, GINI index (Eini-Zinab et al., 2020) or prevalence of undernourishment or FAO's domestic food price index (Mechiche-Alami et al., 2021; Mughal and Sers, 2020). The aspect of utilisation is sized by the under-five mortality rate or the use of improved sanitation and the stability dimension is measured by the variability of net per capita food production (Caccavale and Giuffrida, 2020; Mughal and Sers, 2020).

The proportion of undernourished people, estimated by the Food and Agriculture Organization of the United Nations (FAO), reflects the proportion of the population with inadequate dietary energy intake, i.e. the proportion of people who are energy deficient. Cultivation of more land is likely to bring both negative and positive changes in diets and challenges to food safety which can affect nutritional status in various ways.

b. Composite indicators of food security

Two composite indicators are presented in the literature: the Global Hunger Index and the Food Security Index. Some studies (Wiesmann, 2006; Wiesmann et al., 2015) refer to the Global Hunger Index (GHI) as a measure of food insecurity. The Global Hunger Index (GHI) combines four indicators undernourishment, childhood wasting, child stunting, and infant mortality, into one. However, this indicator is not available over a long period of time, which disqualifies its use in this research.

The analysis of food security using this index is based on the WFP consolidated approach. It combines a suite of food security indicators (food consumption score, share of food spendings, people's livelihood strategies) into a composite indicator: the FSI. While interesting as an indicator, it is difficult to calculate because of its descriptive nature and does not allow for easy interpretation in research.

Food security is measured in this essay by the prevalence of undernourishment proposed by FAO. It is measured at household level by estimating the number of people whose dietary energy consumption is likely to fall below established thresholds referred to as dietary energy requirements.

Focusing on the FAO's prevalence of undernourishment indicator, one of its main criticised shortcomings is the way of measuring the quantity of food available for human consumption. It is the result of considering food production, trade, stock changes, non-food uses, and extra-household waste. The food quantity is converted into calories and divided by the population. As a result, the indicator may be understood as a measure of food availability and not food intake (de Haen et al., 2011; Wanner et al., 2016). However, FAO undernourishment prevalence is a known proxy of food energy consumption that complies the DES from food balance sheets (FBSs) (Eini-Zinab et al., 2020). Then, following Soriano and Garrido (2016), it remains the best known and simplest proxy of undernourishment for a macrolevel study and is the indicator commonly used in the literature to monitor severe or chronic food security (Mughal and Sers, 2020).

Another dimension of food security is food utilisation, or consuming a nutritious diet. This means that people make appropriate use of food, based on knowledge of basic nutrition and care, and have access to water and sanitation for preparing food and maintaining proper hygiene (FAO, 2021). To strengthen the analysis of the effects of agricultural expansion on food security, the study uses other food security variables such as improved water sources and improved sanitation facilities. Both are provided by the World Bank (WDI, 2021), and are indicators of the utilisation dimension of food security (Bhattacharjee and Sassi, 2021; Caccavale and Giuffrida, 2020).

This essay uses variables constructed from previous high-quality studies. For example, the institutional quality or governance (Gov) index from Totouom et al. (2019), the food price vulnerability (FPV) index following Combes et al. (2014), the production index (PI) composed of food, grain and livestock production indexes, as well as labour spillovers inspired by Baymul and Sen (2020).

4.1.2.2. Institutional quality index (Gov)

The institutional variable in this essay is the governance index, whose construction accounts for six indicators of institution quality. The index construction follows the methodology described by Totouom et al. (2019). Following its methodology, the institutional quality index constructed using the PCA is the first principal component of the vector of the six indicators of institution quality. This first principal component accounts for about 82% of the total variance in the original data. The building of the governance index has therefore reduced the dimension of the institutional quality indicator by five and preserving 82% of the information in the data. Table 24 in the annexe reports the PCA results.

The aggregate institutional quality index is normalised to obtain positive values that will allow us to have only positive values ranging from 0 to 10. This normalisation is based on the following formula:

$$Gov = \frac{Gov_g - \min(Gov_g)}{\max(Gov_g) - \min(Gov_g)} \quad (\text{eq1})$$

Where Gov_g is the gross indicator of governance, and Gov is the normalised indicator.

4.1.2.3. Food price vulnerability index (FPV)

This variable construction is based on Combes et al. (2014) and Kinda and Badolo (2019). These authors suggest that countries are vulnerable to price shocks if they meet three criteria: high food dependence, high food import weight and low income. High food dependency, as measured by the share of food imports in total household consumption, highlights the importance of food in the basket of goods consumed by a representative household in the country. The larger the household's basket of goods, the more food prices will affect it. A substantial level of food imports, measured by the ratio of food imports to total imports, underlines the country's high dependence on food imports. The level of income, measured by GDP per capita, highlights a country's ability to provide food safety nets for domestic consumers. The price vulnerability index is a weighted average of the share of food imports in total household consumption; the share of food imports in total imports of goods and services and the inverse of the level of GDP/head.

4.1.2.4. Production index (PI)

In the literature review, it was established that dimensions of food security are sometimes interrelated (Kinda and Badolo, 2019; Mughal and Sers, 2020). To assess the effects of food availability on undernourishment, the study uses a production index. This index is constructed from three well-known indexes: (i) the food production index (ii) the cereal production index and (iii) the animal production index. A 'production index' is constructed using principal component analysis (PCA). This index is considered the wedge of the availability dimension of food security.

The composite food production index is the weighted arithmetic average of the three production indexes. This principal component accounts for 83.2% of the total variance of the original data. This means that the construction of the index has reduced the dimension of the food availability indicators by two while preserving 83% of the information in the data. Results of the PCA are reported in table 25 in annexe.

The aggregate production index is normalised to obtain positive values that will allow us to obtain only positive values ranging from 0 to 100. It is normalised using the following formula.

$$PI = \frac{PI_g - \min(PI_g)}{\max(PI_g) - \min(PI_g)} \quad (eq2)$$

Where PI_G is the gross indicator, and PI_N is the normalised indicator.

In line with Kinda and Badolo (2019) which shows that cereal production index reduces the proportion of undernourished people in developing countries, the expectations are that production index (PI) and undernourishment variables to have an inverse relationship.

4.1.2.5. Building the variable labour spill overs

Timmer (2017b) holds that food security and labour movements are mutually dependent. It is expected that the movement of labour out of agriculture will have an effect on food production and the incidence of undernutrition. These movements are of two types, according to Baymul and Sen (2020). From agriculture to industry and from agriculture to service sectors. They are calculated as follows:

$$Indspill_{it} = indsh_{it} - agrsh_{it} \quad (eq3)$$

$$Scespill_{it} = scesh_{it} - agrsh_{it} \quad (eq4)$$

Where $agrsh$, $indsh$ and $scesh$ represent the shares of agricultural, industrial and service labour force respectively, in the total employment of country i in year t .

It is expected that movements from agriculture to industry (*indspill*) reduce the proportion of undernourishment people and the services spill over (*scespill*). Indeed, both are facing structural transformation, which should moderate undernourishment.

4.1.3. Descriptive statistics of variables and graphical analysis

The descriptive statistics provide the broad characteristics of the variables and their stationarity level. The graphical analysis shows the land expansion paths in sub-Saharan Africa and the link between undernourishment and agricultural land expansion. This is done by using scatterplots for within and between variation. After these presentations of preliminary relationships, the econometric models are estimated.

4.1.4. Stationarity test

This tool is used to analyse the presence of unit root in time series, using the Levin-Lin-Chu tests and the Fisher test when necessary. For example, when the series fails to have strongly balanced data, as required by the LLC test. The two tests are of first generation because they consider the absence of correlation between individuals. The Fisher test is a nonparametric test, whereas the LLC test is a parametric test.

Levin and Lin (Levin et al., 2002) are the first authors to use and analyse unit root tests. These tests are used to determine the integration order of variables and to check the existence of long-run relationship between variables. According to Blot and Cochard (2008), those tests are prior steps of the cointegration analysis, with the final objective to avoid fallacious regressions on panel data. Generally, the stationarity of a variable must be demonstrated by at least two tests because the stationarity results can vary according to the selected test. Following Hurlin and Mignon (2005), first-generation tests are used. The authors of the LLC test assume the simplest form of heterogeneity which is based on the existence of individual specific constant, but hold the hypothesis of homogeneity of other model parameters and the autoregressive root. The restrictions of this test have led to the creation of new tests accounting for more specificity.

These authors use the simplest form of heterogeneity based on the existence of constants specific to each individual. However, they retain the assumption of homogeneity of the other parameters of the model and, in particular, of the autoregressive root. The restrictive nature of these tests has led to the development of new tests which take into account a wider heterogeneity of the dynamics of the series studied (Im et al., 2003; Maddala and Wu, 1999). Under the alternative hypothesis, these tests allow not only heterogeneity in the autoregressive root but also heterogeneity in the presence of a unit root in the panel.

For small T the MW test slightly dominates the IPS test in terms of test power. For large T (T= 50 or 100), the powers are comparable, but the size distortions are smaller with MW. As with any nonparametric approach, the Maddala and Wu test is not a victim of specification error on the residual's distribution (assumed to be normally distributed in IPS). Maddala and Wu (1999) show that in all cases IPS and MW > LLC. In terms of power (corrected by T), the MW test performs better than the IPS test. The stationarity test results will guide the process of estimation strategy.

4.2. Estimation strategy

The estimation technique depends on the stationarity of variables, especially the dependent variable. This subsection a baseline model is presented in, and all variables and expected signs are justified.

4.2.1. The baseline model

Our baseline model has the following form:

$$Y_{it} = \alpha_0 + \alpha_1 \text{aland}_{it} + \beta_{it} X_{it} + \varepsilon_{it} \quad (\text{eq5})$$

Where α_0, α_1 and β_i are the vectors of parameters to estimate. ε is the error term by assumption, normally distributed. Y_{it} , is the dependent variable capturing undernourishment. It refers to the proportion of people undernourished in country i at period t . The variable aland_{it} is the variable of interest capturing agricultural land expansion. X_{it} is the set of control variables, including governance, socio-economic variables, and other variables as justified in the next paragraph.

To estimate the model (eq5), this work uses methodologies used by other studies (Kinda and Badolo, 2019; Barbier, 2020; 2021). The studies one and two-way fixed and random effects panel regression, to assess the land expansion on food security. The choice of the best estimators to interpret is provided by the results of the Hausman test. However, the results obtained are inconsistent because of potential bias of endogeneity. The second methodology used in the study, takes into account the possible risk that endogenous variable can be explained by its previous values. To account for this new specification, the model is written as:

$$Y_{it} = \alpha_0 + \gamma Y_{i,t-1} + \alpha_1 \text{aland}_{it} + \beta_{it} X_{it} + \varepsilon_{it} \quad (\text{eq6})$$

The estimates of this model in equation 6, by Ordinary Least Squares (OLS) and General Least Square (GLS) are both inconsistent. The endogeneity is caused by the introduction of the lagged dependent variable. Better alternatives are to use System Generalised Method of Moments (SGMM) following Arellano and Bover (1995) and Blundell and Bond (1998). Additional argument of using the GMM, includes that the important econometric condition of a short T (16) and a large N (28) is respected.

In the presence of a lagged dependent variable, the model is shifted from the static context to the dynamic panel model. Estimating the model through either OLS or GLS technique will create an important bias, known as the 'Nickell Bias'. According to Nickell (1981) while OLS estimators may be biased upwards, fixed effects may be biased downwards. Consequently, to obtaining consistent and efficient estimators, the study opts to apply the GMM proposed by Arellano and Bond(1991), Arellano and Bover (1995) and Blundell and Bond (1998).

Several reasons motivated the choice of the GMM. The GMM method is regularly used to solve econometric problems such as heteroscedasticity, endogeneity, over identification and validity in the literature. Baum et al. (2003) hold that heteroscedasticity is always present in empirical studies and best issues to solve it is to use the GMM estimator. Similarly, GMM is used to gauge instrument strength (Bazzi and Clemens, 2013). Theoretically, the endogeneity issue may arise because of reverse causality, measurement errors or omitted variable bias. Arellano and Bover (1995) and Blundell and Bond (1998) then pose the use of GMM estimator to address the endogeneity problem. This relies on the ability of the GMM of treating the endogeneity of all explanatory variables by using their lagged values (in terms of level and first difference) as instrumental variables.

Moreover, the Sargan and Hansen tests of over-identifying restrictions and the test of autocorrelation are used in order to ensure the validity of the instruments used for the estimations. A GMM estimator can be constructed by using valid internal instruments and which are based on differencing the regressors. When lagged levels of the exogenous variables are used as instruments, this refers to the difference GMM. Nevertheless, due to the different shortcomings of the difference GMM (D-GMM), a System GMM (S-GMM) estimator which uses lagged differences of both the dependent and explanatory variables as instruments, is used. However, Windmeijer (2005) concludes from Monte Carlo simulations that the estimated asymptotic standard deviations of the two-step GMM estimator can be biased downwards in a finite sample. Using Windmeijer (2005)'s correction procedure, we eliminate such a bias. The two methods of estimating dynamic panel regression are used to see whether relationships between variables within the model are robust to different estimation methods.

The robustness analysis is in two steps. In the first step, equation 6 (eq6) is re-estimated with year averages. The long time dimension (2001-2018) allows to construct the observations as an aggregated five-year average, thus eliminating short-term fluctuations due to white noise in the analysis, which may appear substantially (Asongu and Nwachukwu, 2017; Mulindabigwi Iraduku, 2017). The second advantage of using five-year averages of data is to limit the proliferation of instruments that invalidate the results (Asongu and Nwachukwu, 2017; Islam, 1995). Following the reestimation using the five-year average, the impact of agricultural land expansion on food security is assessed by utilising other

variables of land expansion. Other indicators include arable land, cereal land, and forest area (Tan, Chen, et al., 2022). For simplicity, agricultural land is the land area dedicated to permanent crops, whereas arable land is dedicated to temporary crops. Cereal land refers to dry grain production land. It is critical to mention that forest area is linked to land-use expansion. According to findings, the latter is the first cause of the former (Hu et al., 2021).

In the second step of the robustness analysis, the study switches the response variable of food security to water and sanitation. They are essential for both availability and utilisation pillars of food security. Moreover, food utilisation goes beyond having the right food, but requires changing behaviours related to feeding and child care. It also requires access to and correctly using safe drinking water, hygiene, and sanitation services. Safe drinking water and hygienic sanitation are the requisites for the effective utilisation of food (Bhattacharjee and Sassi, 2021). Though water is an essential input to food systems activities, cooking, drinking and food processing (Linderhof et al., 2021), insufficient access to water and sanitation facilities is strongly linked to a significant risk for diarrheal disease and other illnesses, which can result in the inadequate absorption of vital nutrients (Soriano and Garrido, 2016). Furthermore, poor quality of drinking water can result in water-borne diseases that hamper the proper food use (FAO, 2016; FAO et al., 2015). Following several studies (Bhattacharjee and Sassi, 2021; Caccavale and Giuffrida, 2020) the essay uses the share of the population using at least basic sanitation and drinking water services to capture the utilisation dimension of food security.

Thus, the study is a pioneer as it uses water and sanitation to proxy food security at macro level and its influence due to agricultural land expansion. Later on, we provide an analysis for different milieus for the total population and for both urban and rural milieus.

4.2.2. Justification of variables in the model and expected signs

Table 1 summarises the expected signs of different variables on undernourishment prevalence and the justification follows. Agricultural land (*aland*) is the main interest variable and refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Following theoretical analysis of Keating et al. (2014), and empirical analysis of Kinda and Badolo (2019) it is expected that agricultural land positively affects food security.

For robustness the study uses other variables related to agricultural expansion. For instance, arable land, cereal land, forest area and permanent crop land. Arable land includes land defined by the FAO as land under temporary crops, temporary meadows for mowing or pasture, land under market or kitchen gardens, and land temporarily fallow. Land under cereal production refers to harvested area for dry grain such as wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed

grains, in percentage of land area. Forest area is land under natural or planted stands of trees, whether productive or not, and excludes tree stands in agricultural production systems as fruit plantations and agroforestry systems, trees in urban parks and gardens. Permanent cropland is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. It includes land under flowering shrubs, fruit trees, nut trees and vines (WDI, 2021).

The previous subsection described how the production index (π) is constructed. This methodology extends beyond what the literature (Mughal and Sers, 2020; Kinda and Badolo 2019) actually provides. The study assumes that the production index has a negative relationship with the undernourishment variable. Intuitively, food security is enhanced by an increase in food production and livestock. The higher the quantity of food produced, the more people will have access to it, which decreases the proportion of undernourished people.

Table 1 : Expected signs of variables explaining undernourishment

Names	Labels	Expected signs
<i>aland</i>	Agricultural land	–
<i>Pi</i>	Production Index	–
<i>lnco2</i>	CO2 emissions (kt)	–/+
<i>lngdpcap</i>	Gross domestic product per capita, constant	–
<i>Fpv</i>	Food Price vulnerability index	–
<i>popg</i>	Population growth	–
<i>rurpop</i>	Rural population (% of total population)	–/+
<i>indspill</i>	Spillover from agriculture to industry	
<i>Scespill</i>	Spillover from agriculture to service	
<i>Tb</i>	Incidence of tuberculosis (per 100,000 people)	–
<i>Phiv</i>	Prevalence of HIV, total (% of population ages 15-49)	–
<i>Water total</i>	Improved water source (% of population with access)	
<i>Sanitation total</i>	Improved sanitation facilities (% of population with access)	
<i>Water rural</i>	water source, rural (% of rural population with access)	
<i>Water urban</i>	water source, urban (% of urban population with access)	
<i>Sanitation urban</i>	sanitation facilities, urban (% of urban population with access)	
<i>Sanitation rural</i>	sanitation facilities, rural (% of rural population with access)	
<i>gov</i>	Governance index	–

Source: author

The variable CO2 emissions in kilometric tons (kt) is used to proxy environmental quality (Asumadu-Sarkodie and Owusu, 2016; Avom et al., 2020). Following those studies, CO2 emissions and undernourishment are expected to disclose a direct relationship. Theoretically, as the environment deteriorates, food production should decline causing an increase in the number of people undernourishment prevalence.

To capture institutional effects on food security studies have used the civil conflicts (Kinda and Badolo, 2019) or the civil freedom index (Burke et al., 2009; Tankeu, 2021). In this study the a priori

relation is that there is a negative relationship between governance index and undernourishment. This implies that improving quality of institutions helps to alleviate undernourishment.

Food price vulnerability: Sub-Saharan Africa is the most vulnerable region to price shocks in the world (Combes et al., 2014) and this vulnerability increases food availability (Kinda and Badolo, 2019). As shown in figure 6, the built food price vulnerability index (FPV) has a negative slope, with its highest values recorded between 2001 and 2008. A negative vulnerability shock can increase household food consumption. It is in this way that sensitivity to price shocks for food creates and accelerates food insecurity. Then one expects FPV to have a positive effect on undernourishment.

Economic growth ($lngdpcap$) influences food demand and consumption. Soriano and Garrino (2016) find that income growth increases the purchasing power, and accelerate the effects of food policies aimed at reducing undernourishment. Analysing the food security effects of agricultural land expansion, this study foresees a negative relationship between per capita income and undernourishment.

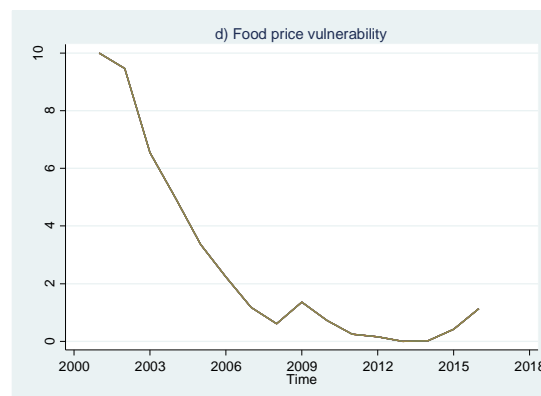


Figure 6: Food price vulnerability-built index
Source: author

A simple justification is owed to Keynes' psychological fundamental law, which stipulates that 'as income increases, consumption increases but at a slower rate'. When people's consumption increases as a result of increased income, the proportion of undernourished decreases.

Meddeb (2011) says factors influencing demand for food products can either promote food security or aggravate food insecurity. Molotoks et al. (2020) hold that population growth is one of the dominant drivers of undernourishment prevalence. Introduction of population growth allows to understand how demographic changes can alter the food security of Sub-Saharan Africans. Thus, the expected relationship between population growth and undernourishment is negative.

Rural population is the second demographic proxy introduced in the baseline model. Despite rural residency can positively influence undernourishment (Desyibelew and Dadi, 2019), two possible

relationships can happen. First, rural population growth can alleviate population undernourishment if it stimulates production and food availability. On the other hand, growth of the population in remote areas can depict a direct relationship with undernourishment if the population is not producing enough food to survive.

Bloem (2019) guides the present reflection on the labour movements' effects on food security. According to Timmer (2017a), there is a relationship between sectoral shifts and food security. Hypothetically, movements from agriculture to industry (*indspill*) reduce the proportion of undernourishment people as well as the spillover services (*scespill*). Indeed, movements from the agricultural sector to the service sector can worsen undernourishment, as fewer people produce.

In this pandemic context, it can be interesting to consider how infectious diseases influence the proportion of undernourished people. To proxy pandemic and epidemics, the study mobilises the prevalence of HIV (*phiv*) as the percentage of the population aged 15–49 years and incidence of tuberculosis (*tb*). Following Nchanji and Lutomia (2021). Both variables should show positive results.

5. Results and Discussion

The section comprises the descriptive statistics, the estimated results and robustness check.

5.1. Descriptive statistics

The features of all the variables are given in table 2. The panel is unbalanced as the number of observations differs from one variable to the other. On average, the prevalence of undernourishment is 21% in the study population. The lowest rate observed in South Africa between 2004 and 2011, which shows increased food security, is 3.5%. In contrast, the lowest levels of food security are observed in Angola and Sierra Leone, with undernourishment rates of almost 67.5%.

Agricultural land (*aland*) is approximately 50% across the sample. There is relative variability around the average. Some countries such as Nigeria in 2007 showed 81% agricultural land percentage. South Africa showed a 80% between 2001 and 2005. Based on this particular case, a direct relationship between agricultural land expansion and the prevalence of undernourishment can be expected.

The analysis of the aggregate production index variable shows an average value of 58.75. Hence, food production over the whole period and for the countries in the study's sample is just average. Looking ahead, the environment variable (*CO2*) in logarithm, shows an average of 8.04 kilotons (kt). The variable appears to have a small dispersion centred around this same mean, justified by a standard deviation of 1.6.

Table 2: Descriptive statistics

	N	Mean	SD	Min	Max
Prevalence of undernourishment	594	20.70993	11.39919	3.5	67.5
Sanitation total	593	32.746	20.58	3.087	95.508
Sanitation urban	594	44.021	19.543	10.086	95.969
Sanitation rural	593	24.19	20.894	.892	95.185
Water total	594	63.383	16.087	19.713	99.867
Water urban	594	83.183	9.047	59.53	99.922
Water rural	594	49.977	17.711	6.916	99.828
Agricultural land	512	49.4987	17.56528	18.11414	80.92054
Production Index	594	58.75448	17.73957	7.88e-15	100
CO2 emissions	528	8.044507	1.61853	3.938431	13.12857
Governance Index	493	4.396999	2.259467	5.02e-16	10
GDP p. capita	448	7.118705	.9947559	5.272348	9.224504
Food price vulnerability	432	2.573883	3.198748	0	10
Population growth	583	0.0240085	.00988	-.0933025	0.0462968
Rural population	594	58.51334	16.65792	10.63	85.302
Industry spillover	528	-0.3830777	.2873063	-0.85659	0.29822
Service spillover	528	-0.1644641	.3864358	-0.80326	.6727833
Incidence of tuberculosis	594	328.9276	315.3675	11	1590
Prevalence of HIV	576	5.647396	7.392179	0.1	28.9

Source: author.

Economic growth per capita is taken as a logarithm and has a mean of 7.12 and a low standard deviation of about 1. In the sample, the logarithm of the lowest standard of living is \$5.27 while the logarithm of the highest standard of living is \$9.22.

Concerning demographic variables, the population growth rate (*popg*) has an arithmetic mean of 2%. The minimum shows a negative growth rate equal to (-9%) and the maximum growth rate is 4.6%. Furthermore, it is noted that the rural population is 58.51% of the total population. However, it may hide strong disparities between countries in the whole sample.

Finally, the health variables (*tb* and *phiv*) have averages of 329 per 100,000 people and 6 per 100 people respectively. Tuberculosis incidence is 1590 per 100,000 people, and the highest HIV prevalence is 29% of the population aged 15–49.

5.1.1. Stationarity Results

Table 3 below presents for each variable, the probability value associated with the Levin – Lin and Chu (LLC) statistic, and that associated with the Fisher (Z or L) statistics. When the P-value is less than 10%, 5% or 1%, then the variable is stationary at the chosen threshold; otherwise, the null hypothesis of non-stationarity of the variable is accepted

The table provides the results on stationarity. It reveals that all variables are stationary at level. The Levin-Lin and Chu test, which is a parametric test, does not admit variables whose data are strictly balanced. However, this test informs that undernourishment variable (*undnrsh*) as well as the variables of interest (*aland*) and control variables are all stationary at level. A more powerful

stationarity diagnosis with the Maddala and Wu test provides the same results. Indeed, this test is based on the hypothesis of a nonparametric distribution of the variables to be tested. Thus, the results obtained corroborate the LLC test results. In conclusion, all variables are stationary at level.

Table 3: Stationarity results

Variables	LLC T-stat	Fisher Z or L-stat	Decision
Undernourishment	-3.485***	-3.19***	I(0)***
Sanitation total	-3.52***	-6.692***	I(0)***
Sanitation urban	-3.34***	-1.498**	I(0)***
Sanitation rural	-2.04**	-1.976**	I(0)***
Water total	-7.012***	-4.370***	I(0)**
Water urban	1.873**	-2.534***	I(0)***
Water rural	-3.428***	-2.431**	I(0)***
Agricultural land	-6.037***	-2.319**	I(0)***
Governance Index	-5.370***	-2.642**	I(0)***
GDP per capita (log)	-3.534***	2.01**	I(0)***
Cereal land	-2.031**	-3.00**	I(0)**
Population growth	-15.69***	-5.52***	I(0)***
CO2 Emissions	0.0315***	-2.34***	I(0)***
Population growth		-2.04**	I(0)**
Rural population	-7.692***	-7.12***	I(0)***
Industrial spillovers	-2.498***	1.73**	I(0)***
Service spillovers	-1.976**	-3.28***	I(0)**
Food price volatility		-15.01***	I(0)***
Incidence of TB	-9.983***	-3.52***	I(0)***
Prevalence HIV	-6.388***	-11.69***	I(0)***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: author.

5.1.2. Analysis of undernourishment trends in sub-Saharan Africa

This subsection presents a graphical analysis and visually explores the links between undernourishment and the evolution of agricultural land. The panel structure of the data allows to look at these relationships from two perspectives: first, through the prism of total variation and second, through the prism of within-country variation.

5.1.2.1. Undernourishment and agricultural land: Overall variation

With the aid of figure 7 (next page) which focuses on the observation of the total variation, the figure shows an inverse relationship between the variables arable land and undernourishment.

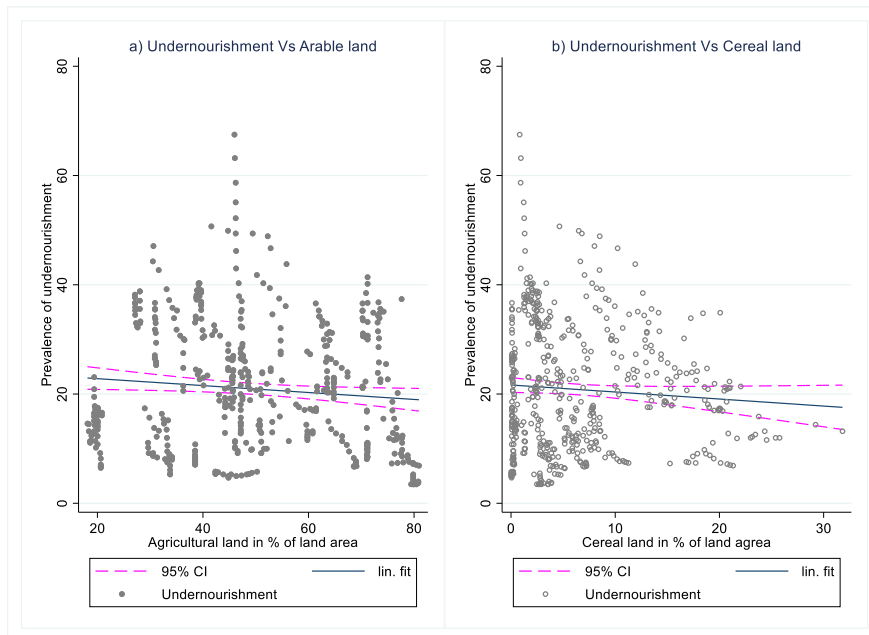


Figure 7: Undernourishment prevalence against land

Source: author.

Indeed, agricultural land expansion accompanies a reduction in undernourishment in Sub-Saharan African countries (figure 7a). The slope of the fitting line, albeit flat, attests to an existing relationship. This raises doubts about agricultural expansion's ability to curb undernourishment in sub-Saharan Africa. Similarly, the second graph (Figure 7b) shows an analogous relationship between undernourishment prevalence and cereal land increase. Indeed, as more land is converted to cereal production, the dietary status of populations improves as explained by Ngoma et al. (2021). This second result supports the first, which shows that agricultural land expansion can reduce undernourishment in sub-Saharan Africa. The perception of this relationship may differ if one changes the angle of observation or analyses the intra-country variation.

5.1.2.2. Undernourishment and land expansion: Within variation

Referring to figure 8, the findings highlight a direct relationship between the two variables. The increase in agricultural land is inversely related to undernourishment. Indeed, agricultural extensification within each country is accompanied by a reduction in the number of undernourished people in these countries (figure 8a).

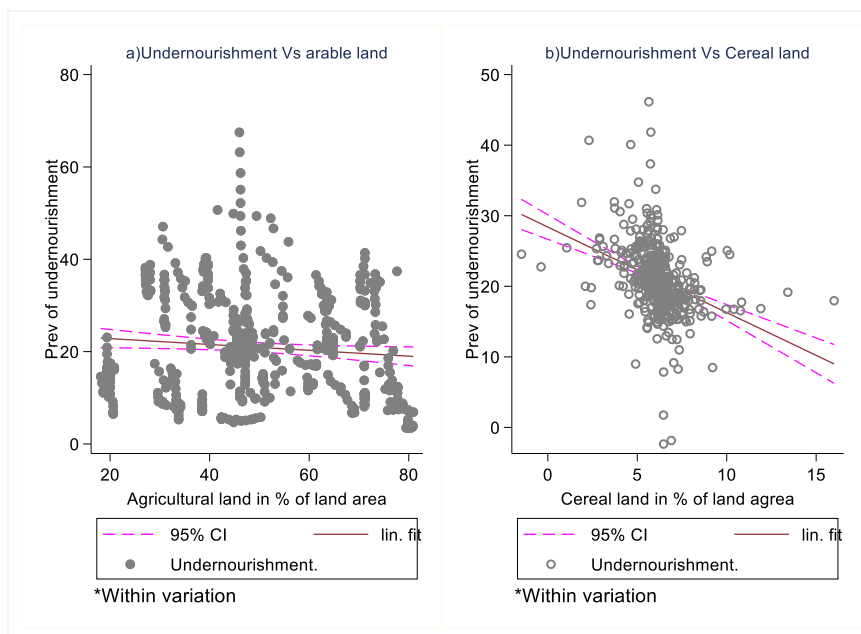


Figure 8: Undernourishment prevalence, within variation
Source: author.

Equally, an increase in the area of land devoted to cereal crops is negatively associated with the number of undernourished individuals (figure 8b). This result is intuitive and similar to the one highlighted earlier in the total variation analysis. It is also supported by previous studies (Keating et al., 2014; Mughal and Sers, 2020). However, the slope appears to be steeper in the analysis of within-country variance than the slope observed in the analysis of total variation.

5.2. Results of the estimation of the econometric model

This subsection interprets the results of the basic model, enriched with several control variables. To assess the robustness of the parameters estimated, fixed effects (FE), random effects (RE) and the generalised method of moments (GMM) are employed. The first two methods can provide biased estimates, as they are inappropriate for the introduction of the lagged endogenous variable as an explanatory variable in the model. This is considered in the third method (GMM). The Hausman test helps choose between FE and RE estimates. Later, the two-step GMM method provides relevant parameters to shed more light on the investigated relationship. Finally, the relationship goes through numerous robustness checks.

5.2.1. Estimation of the model with fixed and random effects and Hausman test

The table 4 provides couples of four models, estimated with fixed and random effects respectively, to analyse how expansion of agricultural land relates to the prevalence of undernourishment in Sub-Saharan Africa.

The fixed effects (FE) estimated coefficients show a negative relationship between our dependent and main independent variables. At the outset, the expansion of agricultural land reduces undernourishment in Africa. Referring to the models (FE1 – FE4), a one-percent increase in agricultural land, relative to the total area of the country, reduces the prevalence of undernourishment by 0.35 at least. The results are significant at the threshold of 1%.

Table 4: Effects of agricultural land expansion on undernourishment, FE and RE

Dependent Variable : Prevalence of undernourishment								
Variable	Fixed Effects (FE)				Random Effects (RE)			
Agricultural land	-0.415*** (0.115)	-0.358*** (0.130)	-0.398*** (0.126)	-0.432*** (0.121)	-0.194** (0.0791)	-0.138 (0.0873)	-0.180** (0.0872)	-0.229*** (0.0873)
Production Index	-0.127*** (0.0192)	-0.135*** (0.0242)	-0.0869*** (0.0242)	-0.0700*** (0.0230)	-0.148*** (0.0161)	-0.139*** (0.0212)	-0.0951*** (0.0213)	-0.0945*** (0.0210)
CO2 emissions	-1.633** (0.820)	-1.435 (1.020)	-0.328 (1.088)	1.118 (1.046)	-1.319** (0.673)	-1.484* (0.851)	-0.699 (0.856)	-0.205 (0.845)
Governance index		-1.237*** (0.352)	-1.712*** (0.360)	-1.682*** (0.349)		-1.198*** (0.333)	-1.744*** (0.343)	-1.628*** (0.332)
GDP p capita		2.767 (2.590)	-1.409 (2.721)	-6.591** (2.683)		0.201 (1.765)	-0.880 (2.039)	-1.918 (2.054)
Food price index		0.0908 (0.110)	0.240** (0.112)	0.0712 (0.110)		0.0432 (0.106)	0.206* (0.106)	0.153 (0.104)
Population Growth			298.7*** (65.95)	248.4*** (62.60)			292.5*** (63.82)	257.7*** (61.97)
Rural population			0.180 (0.126)	0.686*** (0.139)			0.231** (0.0974)	0.442*** (0.107)
Industrial spillover			-19.49*** (6.678)	-14.58** (6.337)			-20.02*** (6.260)	-14.74** (6.147)
Services spillover			25.13*** (5.761)	23.53*** (5.436)			24.91*** (5.394)	22.04*** (5.260)
Incidence of tb				-0.0209*** (0.00320)				-0.0164*** (0.00282)
Prevalence of VIH				0.0666 (0.375)				0.667** (0.269)
1.landl (1 if landlocked)								-5.020 (5.030)
Constant	61.75*** (8.048)	44.07** (18.77)	44.19* (23.97)	50.08** (22.67)	49.47*** (6.052)	52.33*** (12.23)	30.35 (18.59)	28.86 (18.43)
Observations	512	406	406	406	512	406	406	406
Number of id	32	28	28	28	32	28	28	28
Adj R2	0.315	0.311	0.379	0.449				
F-Stat	89.56***	35.98***	28.43***	30.74***				

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: author.

The interpretation remains the same for random effects (RE) estimates. According to the coefficients obtained by the random effects estimation technique, each model (RE1 – RE4) shows a negative relationship between agricultural land expansion and undernourishment

The Hausman test (table 5) invalidates one of the two estimators obtained from fixed or random effects. A quick comparison of the different coefficients obtained by the two estimation techniques shows that the coefficients of the variables remain essentially the same. Under the null hypothesis of the Hausman test, the difference in coefficients is not systematic.

Table 5: Hausman Test

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho;
Test: Ho: difference in coefficients not systematic
chi2(10) = 23.01
Prob>chi2 = 0.0107

Source: author.

Statistically, the $\chi^2(10) = 23.01$ is significant at a 1% level. The result suggests that the null hypothesis of an unsystematic difference in estimators (b and B corresponding to FE and RE respectively) cannot be accepted. Therefore, there is just a 1% chance of being wrong to argue that the difference in estimators is systematic. The test validates the alternative hypothesis, which means that coefficients B obtained by the random effects (RE), are efficient and under the null hypothesis.

Although Hausman's test chose random effects rather than fixed effects (OLS), neither of them can be interpreted as they both suffer from two main limitations, related to endogeneity. Firstly, it is the relationship between the dependent variable and itself, and secondly it is the relationship between the independent variable and the dependent variable. Indeed, the use of the ordinary least squares technique and the random effects method makes it possible to identify pure correlations between the variables of a model. However, these techniques provide biased estimators because they do not address endogeneity in the model. Consequently, these estimation techniques are incompatible with dynamic model specifications.

The level of food security in the current year can be determined by its values in previous periods. This leads to the introduction of a lagged dependent variable in the model. According to Nickell (1981), in the presence of a lagged dependent variable, while OLS estimators may be biased upwards, fixed effects may be biased downwards. Anderson and Hsiao (1982) suggest a first-differenced transformation to eliminate fixed effects.

In addition to this problem, the most prominent source of endogeneity concerns the possibility of bidirectional causality between the explained variable and one or more of the explanatory variables. This work explores the effects of agricultural land expansion on food security. However, other studies

show an inverse causal link. For example, food security indicators support agricultural land expansion (Keating et al., 2014; Qi, 2014; Rulli and d'Orico, 2014; Wood et al., 2004). This reverse causality can be a source of bias. However, it is not addressed by the fixed effects model, nor the random effect model.

To take into account these partial sources of bias, the final econometric specification is based on a GMM approach (Blundell and Bond, 1998). This approach instruments the independent variables with their lagged differences and lagged levels. The GMM system was specifically developed for the estimation of dynamic panel data equations with persistent dependent variables and potentially endogenous independent variables (Bond, 2002; Arellano, 2003; and Bond et al., 2001). Considering Anderson and Hsiao (1982), we employ both difference and system GMM estimators.

5.2.2. Estimation of the model parameters with Generalised Method of Moments

Table 6 provides couples of four models, estimated with difference and system Generalised Method of Moment (GMM). They constitute the main results of this essay, and help to assess the undernourishment effects of agricultural land expansion in Sub-Saharan Africa.

Global assessment of the quality of the estimated model is statistically satisfactory for four reasons. Firstly, the dependent lagged variable introduced in all model turns out to be positive and lower than unit. Moreover, all the coefficients are significant at the threshold of 1%. It indicates that the model and all specifications are convergent to the estimated parameters. Secondly, the number of instruments is lower than the number of observations as required. This means there is no proliferation of instruments. Thirdly, the AR1 coefficients are significant while the AR2 are not, confirming the presence of first order autocorrelation but absence of second and subsequent orders of correlation. Fourthly, the model specifications are not overidentified, both Sargan and Hansen Over Identification Restriction (OIR) reject the null hypothesis of Over Identification.

The coefficients of our estimates are good in general. The GMM estimates show that agricultural land expansion and undernourishment are negative. This relationship is robust to the different specifications of the basic model, and to the estimation technique. In the models estimated by the GMM method in difference (1 - 4), a 1% increase in agricultural land leads to a reduction in the undernourishment prevalence in the order of 11 - 16 percentage points. The results are statistically significant at the 1% level.

A projection into the other specifications estimated using system GMM (columns 5 - 8) shows that the variable keeps its negative sign. Moreover, the significance increases. The expected effect of a one percent increase in agricultural land on undernourishment prevalence is between 6.7 and 12

percentage points. This relationship converges with studies in the literature, which argue that expanding agricultural land improves access to food (Keating et al., 2014; Rulli and D'Orico, 2014; Marselis et al., 2017). Thus, exploiting the latent land potential for agricultural purposes in Africa is a major way of combating undernourishment in the region.

Table 6: Effects of agricultural land expansion on undernourishment, D-GMM and S-GMM

	D-GMM				S-GMM			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prevalence of Undernourishment								
Undernourishment,(t-1)	0.711*** (0.0714)	0.664*** (0.0802)	0.777*** (0.118)	0.785*** (0.110)	0.957*** (0.0665)	0.855*** (0.0940)	0.893*** (0.0710)	0.831*** (0.103)
Agricultural land	-0.119** (0.0516)	-0.162* (0.0881)	-0.135* (0.0702)	-0.126* (0.0728)	-0.108** (0.0606)	-0.0678** (0.0370)	-0.104** (0.0503)	-0.116** (0.0464)
Production Index	-0.0427 (0.053)	-0.0464*** (0.0147)	-0.0283* (0.0171)	-0.168*** (0.0175)	-0.0307** (0.0157)	-0.0302* (0.0163)	-0.0475** (0.0124)	-0.0329** (0.0140)
CO2 emissions (log)	3.081 (2.864)	0.103 (0.854)	0.866 (1.139)	1.057* (0.642)	0.842 (0.661)	1.208* (0.674)	0.963 (0.750)	1.566** (0.766)
Governance index		-0.454* (0.285)	-0.404* (0.236)	-0.346* (0.209)		-0.0778 (0.250)	-0.465* (0.258)	-0.613** (0.285)
GDP per capita		2.467 (2.200)	0.848 (2.148)	0.437 (1.660)		0.797 (1.192)	2.060 (1.731)	1.038 (1.325)
Food price vulnerability		0.133** (0.0723)	0.135** (0.0592)	0.119** (0.0503)		0.116*** (0.0323)	0.125** (0.0541)	0.105** (0.0490)
Population growth			6.30*** (2.05)	6.64* (4.35)			5.760*** (2.42)	3.102** (1.466)
Rural population growth			0.0478* (0.0316)	0.0413** (0.0236)			0.0929* (0.0525)	0.166* (0.101)
Industrial spillovers			-0.127*** (0.0346)	-0.526* (0.315)			-0.428** (0.214)	-0.253** (0.107)
Services spillovers			0.308** (0.1187)	1.890 (1.256)			0.2741** (0.1246)	0.140*** (1.354)
Incidence of tb				-0.0128* (0.00843)				-0.00929* (0.00547)
Prevalence of hiv				0.514** (0.207)				0.730*** (0.258)
Constant					-0.524 (4.861)	-8.362 (10.55)	-21.41** (10.58)	-17.10* (9.801)
Observations	448	378	378	378	480	406	406	406
Number of id	32	28	28	28	32	28	28	28
Instruments	8	11	13	15	10	12	16	19
AR1	0.094	0.087	0.053	0.099	0.0397	0.0799	0.0688	0.037
AR2	0.501	0.591	0.913	0.882	0.549	0.763	0.0763	0.754
Sargan OIR	0.2142	0.2389	0.214	0.1109	0.198	0.1806	0.1285	0.1152
Hansen OIR	0.1674	0.2395	0.1746	0.1785	0.102	0.204	0.2463	0.1439
chi2	162.9	427.6	1636	1561	1644	1630	2625	1675

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

According to the physiocracy, the expansion of agricultural land increases support for agriculture and livestock. The output of these products can easily reach the hands of the population through various channels. Our knowledge of the relevant channels remains limited.

Several countries resort to the acquisition of foreign land to fight undernourishment, thanks to the export of food products to the country of origin (Marselis et al., 2017). Acquiring such land for food sovereignty purposes is therefore necessary, as this coefficient indicates.

Besides, the expansion of land is accompanied by an increase in other inputs and factors of production, which ultimately leads to higher production than in the past. This is known as constant or increasing returns to scale. Meaning that, the increase in production, in turn, improves food availability at the local, national or sub-regional levels. This result corroborates the evidence from developing countries that expanding agricultural land reduces the prevalence of undernourishment. (Mughal and Sers, 2020; Kinda and Badolo, 2019; Ramankutty et al., 2018; Marselis et al. 2017) but contradicts others like (Mechiche-Alami et al., 2021; Zabala, 2021; Galeana-Pizaña et al., 2018; Sauer; 2018). Indeed, an increase in agricultural land allows for more agricultural production, thus increasing calories intake for people (Santangelo, 2018), thereby leading to a decrease in undernourishment.

The analysis of the food production index makes it possible to empirically validate the existence of an inverse relationship between the said variable and the prevalence of undernourishment in sub-Saharan Africa. Indeed, an increase in the production index (agricultural and agro-pastoral) lowers the undernourishment rate in Africa. This is supported by all model specifications (1 – 8). The increase of the production index by one unit, will reduce the prevalence of undernourishment by 4 – 16 percentage points with the D-GMM and by 3.02 – 4.7 percentage points, with the S-GMM. Majority of these coefficients have a significance lower or equal to 10%. Although more general, this result is similar to that of the literature (Mughal and Sers, 2021; Ray, 2007), which show that cereal production reduces the proportion of undernourished. Possible explanation is that agricultural production is supported by both land fragmentation and diversified food crop production (Caian et al., 2018) which improve productivity (Deininger et al., 2012) and people nutritional status (Keating et al., 2014). However, it contradicts the findings of Purwestri et al. (2016) which concluded that increases in food production increase sometimes result in high levels of undernourishment, when food is exported to foreign markets.

Variable CO₂ emissions provides a better understanding of the environmental factors that affect the prevalence of undernourishment in Africa. The results show that environmental quality increases undernutrition rates. Significance is found in models 4, 6 and 8, while the rest maintain positive signs. The results demonstrated that an increase of kiloton of carbon by one percent is accompanied by an increase in the number of undernourished people in the range of 0.01 to 0.016 percentage points. This result corroborates those obtained by Sarcodie and Owusu (2016) and Baker and Antilla-Huges (2020). They find that climate variability and CO₂ emissions raise temperatures.. In consequence, the number of droughts and floods increases with three main outcomes: fewer pollinators, higher rate of microbial growth and lower nutritional value of zinc and iron-rich foods. They respectively shrink

food availability, and disturbs food access patterns (Baker and Anttila-Hughes, 2020; Eckelman and Sherman, 2018). This extra trapped heat disrupts many of the interconnected systems in our environment and justify the increased proportion of undernourished people in sub-Saharan Africa. However, this relationship is contrary to that found in Kinda and Badolo (2019).

The introduction of the institutional quality variable (Gov) is done in models 2 – 4 and models 5 – 8. These models show that governance varies in the opposite direction with undernourishment. Indeed, an improvement in the governance quality significantly reduces the prevalence of undernourishment by about 0.35 to 0.45 percentage points (with D-GMM) or by about 0.47 to 0.61 percentage points (with S-GMM). This reduction is significant at 10%. Moreover, the relationship is robust to several specifications. These results are consistent with literature (Ecker and Breisinger, 2012; Rodrik et al., 2004). What justifies this is the centrality of government programming, and the fight against corruption, incivism and the rule of law. They are all catalysts and key regulatory factors that ensure security of people and their investments. In addition, good governance ensures that state enablers (such as finance) are allocated efficiently and timely manner to producers. As a result, the agricultural calendar can be followed and production increased.

The analysis considers two economic variables: growth in gross domestic product per capita and vulnerability to food prices. The estimated coefficients show that the relationship between economic growth and undernourishment is robust in sign. However, the coefficients in all models are not significant. As a result of the increase in GDP/head, there is no effect on the prevalence of undernourishment.

This result shows that the increase in per capita income is not accompanied by an improvement in malnutrition. This can be justified by low economic growth. Malthus' theory maintains that economic growth at an arithmetical rate is incapable of satisfying the resource needs of a population whose growth follows a geometric rate. On the other hand, on the operational level, the result may be the poor redistribution of growth fruits. An allocation of resources that allocates an insignificant share to agriculture finances very little agriculture development. Insufficient public funding hinders research into improved crops adapted to different agro-ecological zones. The productivity of old crops can be reduced by diseases (local or imported). Thus, the improvement in growth, which does not benefit producers, does not improve production either quantitatively or qualitatively, hence the malnutrition. The relationship detected is different from the positive relationship identified in the literature (Soriano and Garrino, 2016; Kinda and Badolo; 2019).

To assess the effect of food price vulnerability on undernourishment in Africa, the study uses the price vulnerability index. The estimated coefficients show a direct relationship between the two

variables. An increase in the food price vulnerability index is accompanied by an increase in the number of undernourished people from 0.12 to 0.14 percentage points with the D-GMM or from 0.11 to 0.13 with the S-GMM. One justification for this relationship is that individuals may lose access to food if its price changes. Such a change may distort food consumption when prices are highly sensitive as in sub-Saharan Africa. All coefficients are significant at the 5% threshold. This result is similar to Combes et al. (2014) who show that a negative shock to price vulnerability increases household consumption.

The third model specification accounts for demographic variables: population growth and rural population growth rates as well as labour movement (industrial and services spillovers).

The estimated parameters of the demographic variables are in line with Malthusian theory. An increase in population growth exacerbates undernutrition. As the population grows, the proportion of undernourished people rises. This result is significant at the 5% level, and can be justified by the precariousness of agricultural production in sub-Saharan Africa, and the low yields obtained from producers. Thus, states high population growth in Africa face important food challenges. This result is similar to that obtained by Tankeu (2021) who shows that population growth reduces food availability in Cameroon. However, the high values of the coefficients show that they should be interpreted with caution.

For the rural population growth variable, it is noted that when it increases by one percentage point, the prevalence of undernourishment increases in a range of 0.047 and 0.16 percentage points. The relationship is robust and only the result of model 4 is significant at 1% level, the others being significant at the 5% threshold. The results are justified because poverty in Africa is mainly a rural phenomenon. Desyibelew and Dadi (2019) show in their microeconomic analysis that living in rural areas increases the risk of undernourishment. A growing rural population increases the number of undernourished people, further destabilizing a rural population with fragile undernourishment status and thus increasing the size of undernourished communities. This result is similar to Tankeu (2021) who shows that in Cameroon, population growth exacerbates food insecurity, captured by price vulnerability.

The observation of structural change variables once again highlights their importance to undernourishment. It emerges that the structural change variables are significant, with a negative sign for virtuous structural change and a positive sign for vicious structural change. The flow of labour from the agricultural sector to the industrial sector (industrial spillover) reduces the prevalence of undernourishment by between 0.13 and 0.53 percentage points. These results are robust and significant at the 1% level. Indeed, the development of agribusiness and agro-industries is essentially

based on agricultural commodities. Justification lies in the reciprocal stimulation of agricultural and industrial products. Thus, industrial activities stimulates agricultural production and contributes to the population's access to manufactured or raw products.

However, when labour shifts from the agricultural sector to the service sector (services spillovers), undernourishment prevalence increases between 0.14 and 0.30 percentage points. All these results are robust and significant at the 5% level. The service sector in sub-Saharan Africa is mainly made up of informal activities, with low productivity, and without spillover effects on agricultural productivity. Food insecurity is caused by weak service sector development. This sector is generally consumer and informal, rather than productive and formal. It is said to be consumer-based because it is not productive, and is predominantly informal, with activities centred on redistribution, small-scale retailing and street vending. As a result, agricultural productivity decreases and increase the number of undernourished people.

The plausible explanation is that there is a lack of integration and connection between the agricultural sector and the service sector. The latter is mainly made up of informal activities, with low productivity, and without spillovers effects on the agricultural sector productivity. As a result, agricultural productivity decreases and causing food scarcity and increasing undernourishment. This lack of integration between the primary and tertiary sectors is rather natural for the primary and secondary sectors (Timmer, 2017a, 2017b). This is evidenced by the emergence of small start-ups and agribusiness firms that process agricultural products and stimulate production in the agricultural sector. Moreover, the dissemination of manufactured agricultural products is a major asset in the fight against undernourishment.

This result sheds light on the imprecise conclusion of Bloem (2019). It would be beneficial to promote structural change towards the industrial sector, towards the emergence of agri-industries and the full development of value chains. It is this strategy that would significantly reduce under-indebtedness in sub-Saharan Africa. These results extend and bring clarity to the study of Bloem (2019) as it specifies which type of structural change leads to the reduction of food security.

In columns 4 and 8, the epidemiological factor is taken into account. The variable tuberculosis incidence and HIV prevalence are epidemiological situations that can account, even approximately, for the effect of the COVID-19 pandemic on undernourishment in sub-Saharan Africa. Two significant and contradictory results emerge from the estimated parameters.

The tuberculosis incidence variable has a negative effect on undernourishment in Africa. This effect is significant at the 10% level. The result is contrary to both theory and intuition. The explanation

provided is that tuberculosis is a chronic disease with a high mortality rate. The first result shows that an increase in the TB epidemic contributes to a reduction in undernourishment. One reason for this is that tuberculosis is the single most common cause of death among single infectious diseases just before HIV/AIDS (World Health Organization, 2022). Approximately 500,000 people die of TB per year in Africa. The negative coefficient can be explained if the TB mortality rate is higher than the prevalence rate of undernourishment. Mortality due to this disease, considered as 'positive checks' in the Malthusian analysis, can explain the demographic regression. This can explain the improvement of undernourishment statistics.

The second result establishes that HIV prevalence produces an intuitive relationship. Indeed, precarious health of individuals makes them unfit for agricultural production, which still relies on physical strength in Africa. It can be seen that in a pandemic situation, the prevalence of undernourishment will increase, due to the drop in productivity, which is itself due to the psychological shock that individuals undergo. In addition to this, confinement over several months also causes the abandonment of crops or significant farming operations, ultimately reducing agricultural production and undernourishment. These results are significant at a level of 1% and corroborate those of Nchanji and Lutomia (2021) and Arouna et al. (2020). The authors show that the COVID-19 pandemic generates disturbances at the field level. These disruptions are transmitted along agri-food chains such as market access, logistics and confinements that impose border restrictions. Ultimately, the impact on the household comes from reduced economic activity, household income, food instability and access, and poverty.

In this sub-section, the suitable tools mobilised for estimation reveal that our theoretical assumption is confirmed. The expansion of agricultural land can help curb food insecurity in Africa, as well as good institutions. This result may change if other assumptions are relaxed. Therefore, other estimation techniques are employed to assess the effect of agricultural land expansion on food security in the next subsections.

The robustness subsection provides robustness analyses by giving on the one hand, estimations of five-year average data and using additional variables of agricultural land expansion and on the other, analysis of the nexus between agricultural land expansion and food security, using additional variables to capture food security.

5.2.3. Robustness check: averaged data and other agricultural land variables

The robustness subsection allows to improve the statistical adequation of the previous estimated parameters. It starts by giving the five-years averaged data estimations, then, estimations with other agricultural land expansion variables.

5.2.3.1. Effects of agricultural land expansion on undernourishment averaged year data

The present results aim to verify the robustness of the previous estimates. Indeed, they show the robustness of the latter. Two observations stand out in table 7, despite the consistent negative relationship between agricultural land expansion and undernourishment.

Table 7: Effects of agricultural land expansion on undernourishment with 5 years average

Variable	Dependent variable: Prevalence of undernourishment							
	D-GMM				S-GMM			
Undernourishment (t-1)	0.382*** (0.107)	0.392*** (0.137)	0.426*** (0.131)	0.385*** (0.145)	0.977*** (0.279)	0.409** (0.203)	0.872*** (0.128)	0.437** (0.0978)
Agricultural land	-0.603*** (0.0429)	-0.345*** (0.0324)	-0.459*** (0.104)	-0.531*** (0.165)	-0.615* (0.331)	-0.337** (0.0561)	-0.106*** (0.0389)	-0.345** (0.0778)
Production Index	-0.0649*** (0.0150)	-0.064*** (0.00429)	-0.0901*** (0.0105)	-0.01564** (0.00665)	-0.0881 (0.0646)	-0.0627*** (0.00436)	0.0108 (0.0602)	-0.0432* (0.0103)
CO2 emissions	2.205 (2.618)	-1.475 (1.764)	3.024* (1.814)	4.446** (1.837)	1.952 (3.310)	-1.370 (2.488)	2.684*** (0.579)	5.995 (5.058)
Governance index		-2.346*** (0.0664)	-2.022*** (0.0127)	-1.912*** (0.235)		-2.321*** (0.129)	-1.687*** (0.478)	-1.351*** (0.487)
GDP per capita		18.67*** (0.284)	12.67*** (2.393)	7.269** (2.878)		18.69*** (0.356)	3.167*** (1.126)	0.652 (3.574)
Food price vulnerability		1.243*** (0.171)	1.300** (0.595)	1.185** (0.603)		1.262** (0.247)	0.724 (1.103)	1.194 (0.716)
Population growth			630.5*** (28.79)	600.1*** (68.69)			233.3* (135.9)	408.3** (63.74)
Rural pop. growth			0.379*** (0.0515)	0.582*** (0.0452)			0.207*** (0.0641)	0.450 (0.396)
Industrial spillovers			1.341*** (0.497)	-1.304 (1.021)			-12.62 (9.184)	-6.881 (3.852)
Services spillovers			3.672 (3.575)	7.391 (5.170)			11.97 (7.285)	6.646 (2.361)
Incidence of TB				-0.0067*** (0.00159)				-0.0121* (0.00328)
Prevalence of HIV				-0.335 (0.751)				-0.163 (0.953)
Constant					33.94 (23.45)	-81.70 (31.13)	-4.756 (12.96)	-58.49 (105.4)
Observations	64	55	55	55	96	83	83	83
Number of id	32	28	28	28	32	28	28	28
Instruments	6	9	13	15	6	8	15	13
AR1	0.0564	0.0584	0.0349	0.0665	0.0897	0.0858	0.0779	0.0895
AR2	0.658	0.365	0.549	0.744	0.141	0.149	0.145	0.605
Sargan OIR	0.405	0.642	0.792	0.785	0.335	0.652	0.338	0.642
Hansen OIR	0.1261	0.2472	0.1427	0.2015	0.1179	0.2212	0.1333	0.1492
F					7.799***	670***	15.98***	11300***
chi2	709***	701***	479.6***	76.31***				

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

First, the coefficients are larger (in absolute values) than in the previous table. Thus, a one percent expansion of agricultural land leads to a reduction in undernourishment prevalence of between 1 and 6 percentage points. This effect is significant over five (05) years. Secondly, it is important to note that the significance of the agricultural land expansion variable is increased when short-term

fluctuations are eliminated. This outcome confirms the theory of land expansion for agricultural activities as a mean of reducing food insecurity.

For other variables such as the production index, the relationship remains negative. This indicates that agricultural and pastoral production continue to significantly affect undernourishment. As for CO₂ emissions, there is a positive relationship with undernourishment. This relationship is justified by the risk that global warming poses to food security. The main consequence of greenhouse gases spread in the atmosphere is global warming. This is followed by season disruption, which reduces agricultural and agro-pastoral production and exacerbates food insecurity for populations.

Other variables such as governance, the price vulnerability index and the incidence of tuberculosis maintain the same relationship with undernourishment prevalence.

First, the coefficients are larger (in absolute values) than in the previous table. Thus, a one percent expansion of agricultural land leads to a reduction in malnutrition of between 1 and 6 percentage points. This effect is significant over five (05) years. Secondly, the significance of the agricultural land expansion variable is increased when short-term fluctuations are eliminated. This finding supports the theory of land expansion for agricultural activities to reduce food insecurity.

Similarly, variables such as governance, the price vulnerability index and the incidence of tuberculosis maintain the same relationship with the prevalence of undernourishment.

5.2.3.2. Robustness check: alternative measures of agricultural land expansion

This subsection assesses the undernourishment effects of agricultural land expansion, measured alternatively. For instance, arable land, cereal land, forest land area and land under permanent crop. Table 8 shows that all variables previously cited have a negative impact on food insecurity.

Forest area and arable land have the greatest coefficients. Forest areas are still a source of food production and pastoral production. By contrast, forests help prevent global warming by reducing CO₂ and greenhouse gas emissions. This improves food production and the reduce food insecurity.

Arable land is a source of crop production consumed daily by populations independently of their milieus. Almost all crop products are raised more than once a year. Therefore, expanding arable land is a way of providing markets and populations with food crops and stuffs to ensure nutrition. This is the reason why expanding land for cereal production has a positive effect and may reduce undernourishment, as in most of the Sahelian part of the continent (Senegal, Mali, Niger, North Cameroon, Chad...) grains are a favourite ingredient of traditional meals, as found by Mughal and Sers (2021).

Table 8: Alternative measures of agricultural land expansion and undernourishment

Variables	Dependent Variable: Prevalence of undernourishment							
	D-GMM				S-GMM			
Undernourishment, (t-1)	0.896*** (0.0762)	0.914*** (0.0780)	0.903*** (0.0794)	0.905*** (0.0774)	0.837*** (0.100)	0.862*** (0.102)	0.849*** (0.105)	0.853*** (0.102)
Arable land	-0.0767* (0.0466)				-0.0939* (0.0483)			
Cereal land		-0.0228 (0.0468)				-0.0136* (0.0228)		
Forest land			-0.1000* (0.0518)				-0.112** (0.0551)	
Permanent cropland				0.285** (0.143)				0.247* (0.139)
Production Index	-0.00485 (0.0129)	-0.00730 (0.00675)	-0.0110 (0.00735)	-0.0106 (0.00706)	-0.00958 (0.0143)	-0.0119* (0.00722)	-0.0167* (0.00859)	-0.0159* (0.00833)
CO2 emissions (log)	1.058 (0.759)	1.074* (0.570)	1.040* (0.601)	1.063* (0.590)	1.060 (0.761)	1.083* (0.568)	1.041* (0.608)	1.069* (0.593)
Governance index	-0.308 (0.262)	-0.289* (0.176)	-0.297* (0.180)	-0.305* (0.182)	-0.398 (0.285)	-0.356* (0.192)	-0.379* (0.201)	-0.384* (0.202)
GDP per capita	1.670 (1.166)	2.078 (1.429)	2.095 (1.393)	2.203 (1.410)	1.128 (1.277)	1.640 (1.552)	1.686 (1.487)	1.781 (1.510)
Food price vulnerability	0.106** (0.0428)	0.107*** (0.0275)	0.110*** (0.0289)	0.113*** (0.0285)	0.104** (0.0482)	0.105*** (0.0306)	0.108*** (0.0322)	0.110*** (0.0316)
Population growth	81.75* (46.26)	79.12*** (17.26)	81.74*** (17.28)	83.38*** (15.86)	93.12* (49.18)	89.23*** (19.56)	92.31*** (19.81)	93.32*** (18.65)
Rural population growth	0.123 (0.123)	0.118*** (0.0424)	0.134*** (0.0418)	0.125*** (0.0410)	0.160 (0.143)	0.151*** (0.0483)	0.170*** (0.0481)	0.159*** (0.0480)
Industrial spillovers	-0.422 (4.338)	-0.365 (2.616)	-0.822 (2.563)	-0.699 (2.485)	-1.430 (4.499)	-1.349 (3.104)	-1.815 (3.024)	-1.585 (2.937)
Services spillovers	2.596 (4.168)	2.191 (2.996)	2.567 (2.941)	2.407 (2.860)	4.031 (4.360)	3.498 (3.600)	3.873 (3.506)	3.636 (3.427)
Incidence of TB	-0.00173 (0.00509)	-0.00140 (0.00177)	-0.00170 (0.00181)	-0.00159 (0.00177)	-0.00300 (0.00544)	-0.00251 (0.00206)	-0.00288 (0.00215)	-0.00275 (0.00212)
Prevalence of HIV	0.232 (0.239)	0.267** (0.133)	0.292** (0.122)	0.275** (0.124)	0.225 (0.249)	0.266** (0.134)	0.298** (0.122)	0.278** (0.124)
Constant					-21.88** (9.606)	-27.44* (14.48)	-25.08* (14.44)	-29.12** (13.80)
Observations	378	378	378	378	406	406	406	406
Number of id	28	28	28	28	28	28	28	28
Instruments	18	18	18	18	19	19	19	19
AR1	0.0813	0.0302	0.0727	0.0598	0.0594	0.0435	0.0487	0.0376
AR2	0.594	0.573	0.613	0.601	0.750	0.702	0.758	0.744
Sargan OIR	0.459	0.349	0.207	0.385	0.616	0.387	0.242	0.459
Hansen OIR	0.0458	0.283	0.841	0.839	0.0823	0.831	0.859	0.797

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The coefficient of permanent cropland however, is positive and significant. This is a sign that the expansion of permanent cropland deteriorates food insecurity. This result is justified because most of the crops such as cocoa, coffee and rubber are produced within these lands dedicated to exportation in European countries. The exceptions are countries such as South Africa, Côte d'Ivoire, which processes half of its cocoa production locally. Agricultural expansion for this purpose is of substantial benefit to developed countries which import these crops for food security. This result converges with that of Mechiche-Alami et al (2021), who show that, in general, agricultural expansions for export or cash crops do not benefit local food security or generate conflicts. Moreover, they contribute to the food security of the populations of the host countries on the one hand. On the other hand, to their economic development when they process these products.

5.2.4. Robustness check: alternative measures of food security

To assess the robustness of agricultural land expansion effects on food security, the study considers its use dimension and proceeds in two phases.

Table 9: Effects of agricultural land expansion on water and sanitation (overall)

Variables	Dependent variable: Sanitation Total				Dependent variable: Water Total			
	Annual		5 years averaged		Annual		5 years averaged	
	D-GMM	S-GMM	D-GMM	S-GMM	D-GMM	S-GMM	D-GMM	S-GMM
Agricultural land	0.0663*** (0.00896)	0.0655*** (0.00954)	0.032*** (0.00513)	0.0568*** (0.0228)	0.01688* (0.00965)	0.0089** (0.00420)	0.0132*** (0.00512)	-0.0396 (0.0321)
Production Index	-0.00727** (0.00343)	-0.00693** (0.00348)	0.0177*** (0.00327)	0.00436 (0.00910)	-0.0846* (0.00488)	-0.00434** (0.00220)	-0.0409*** (0.00936)	0.0103** (0.00444)
CO2 emissions (log)	-0.0565** (0.0287)	-0.0478* (0.0289)	0.889*** (0.0854)	0.345 (0.319)	-0.285*** (0.0886)	-0.154** (0.0707)	-3.662*** (1.254)	2.701*** (0.166)
Governance index	0.0913** (0.0421)	0.0994* (0.0592)	0.152*** (0.0255)	0.164** (0.0657)	0.107** (0.0490)	0.0363*** (0.00973)	-0.612*** (0.0356)	-0.147*** (0.0308)
GDP per capita	-0.5848* (0.337)	-0.8162** (0.339)	-3.095*** (0.160)	0.0566 (0.598)	-0.603* (0.357)	-0.291 (0.192)	-0.640 (1.506)	-1.426 (1.518)
Food price vulnerability	-0.0230** (0.0111)	-0.0233** (0.0116)	-0.315*** (0.0931)	-0.226** (0.0884)	-0.00898* (0.00468)	-0.0147*** (0.00343)	-1.145*** (0.247)	-0.214*** (0.0480)
Population growth	-34.37 (29.51)	-32.91 (29.72)	127.7*** (1.369)	83.79*** (24.15)	-14.36 (9.226)	-1.421 (2.019)	-155.7* (86.32)	80.11** (33.98)
Rural pop growth	-0.0132 (0.0104)	-0.0179* (0.0109)	-0.162*** (0.0206)	-0.206*** (0.0252)	0.0187 (0.0118)	-0.0474*** (0.0147)	0.394*** (0.152)	-0.0474 (0.109)
Industrial spillovers	4.075*** (1.207)	4.149*** (1.086)	-8.887*** (1.735)	-6.052*** (0.227)	2.137*** (0.818)	0.761** (0.302)	17.73** (7.404)	-11.92*** (0.610)
Services spillovers	-2.243** (1.010)	-2.289** (0.939)	6.609*** (1.293)	3.283*** (0.152)	2.092** (0.995)	-0.185 (0.162)	-10.52*** (3.548)	7.714*** (0.867)
Incidence of TB	-0.00054** (0.000210)	0.000396* (0.000220)	0.00166** (0.000722)	0.00223** (0.000967)	-0.00040** (0.000200)	-0.000465* (0.000274)	-0.00278*** (0.000988)	0.000297 (0.00070)
Prevalence of HIV	0.0414 (0.0326)	0.0411 (0.0315)	0.178 (0.150)	0.763*** (0.116)	-0.0679 (0.0562)	-0.0109 (0.0142)	-0.274*** (0.0795)	-0.0178 (0.302)
Constant		-2.323 (3.968)		1.200 (1.053)		-0.599 (1.212)		1.902 (0.110)
Dependent variable (t-1)	0.928*** (0.00947)	0.828*** (0.00977)	0.905*** (0.0329)	0.908*** (0.0450)	0.818*** (0.0136)	0.943*** (0.0162)	0.873*** (0.107)	0.826*** (0.110)
Observations	378	406	55	83	378	406	55	83
Number of id	28	28	28	28	28	28	28	28
Instruments	15	16	15	17	14	15	14	16
AR1	0.0280	0.0343	0.00538	0.000140	0.0244	0.0176	0.0930	0.016
AR2	2.243	2.249	0.548	0.181	0.501	0.351	1.358	0.557
Sargan OIR	0.0791	0.5066	0.583	0.856	0.578	0.2004	0.175	0.577
Hansen OIR	0.304	0.302	0.232	0.296	0.1595	0.2897	0.590	0.318

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2.4.1. Robustness check: total water and total sanitation

Table 9 presents the estimated coefficients for analysis of the effects of agricultural expansion on food security, as captured by improved water sources and sanitation facilities. Estimates are based on both annual and average data. The coefficients obtained show that an expansion of agricultural land is accompanied by an improvement in the utilisation dimension of food security. More specifically, a 1% increase in agricultural land is accompanied by a significant improvement in nutrient intake by the population.

Both crop and livestock production contribute to water pollution (UNEP, 2016), although the type of contamination differs across food production types. In crop production, it is mainly due to unsustainable farming practices like overuse of organic and chemical fertilizers, and over use of pesticides including herbicides. It leads to the leaching of nitrogen, phosphorus and pesticide residues into the soil and runoff into surface waters. Nitrogen and phosphorus contamination of surface waters is also observed in areas with intensive livestock production due to unsustainable management of manure of livestock. These areas also show pathogen contamination (Linderhof et al., 2021). In those cases, more people will access contaminated water, which will degrade population food security.

The direct relationship obtained could be justified by modernisation's slow process. According to Marinoudi et al. (2018) agricultural modernisation process is slow, with a slow adoption rate of chemicals and fertilisers. As a result, the expansion may provide better water access and sanitization facilities. Besides, only permanent crop land expansion appears to threaten water access in Africa.

As a matter of fact, palm oil production in Cameroon, Niger, Tanzania and Zambia causes land to dry out and reduces water access. As a result of the substantial amount of water involved in their production, all nearby water is dried out. However, the model shows that small scale agricultural expansion raises the income of small-holders and improve their capacity to build and to access improved water and sanitation facilities as well.

5.2.4.2. Robustness check: Water and sanitation in urban or rural milieus

Table 10 presents the analysis of the relationship between agricultural expansion and food security, disaggregated by the living environment. It also serves as a robustness and sensitivity analysis.

The estimated coefficients show that the variable of interest is significant for all dependent variables and in all settings. The limited knowledge of our study of the relationship between agricultural land expansion and the use dimension of food security allows us to naively conclude that the latter is sensitive to the former. Agricultural land expansion affects sanitation access negatively in urban areas but positively in rural areas. In contrast, the effect on access to water is positive in urban areas but negative in rural areas. It can be concluded that agricultural expansion in Africa affects the use dimension of food security, and are sensitive to the milieu.

Table 10: Sensitivity analysis

Variables	Dependent variable: Sanitation				Dependent variable : Water			
	Urban		Rural		Urban		Rural	
	D-GMM	S-GMM	D-GMM	S-GMM	D-GMM	S-GMM	D-GMM	S-GMM
Agricultural land	-0.0711** (0.0301)	-0.116* (0.0688)	0.0668*** (0.0189)	0.0646*** (0.0211)	0.0137** (0.00565)	0.01475* (0.00866)	-0.0246** (0.0109)	-0.0302** (0.0144)
Production Index	-0.0228** (0.0106)	-0.0231** (0.0106)	-0.0126* (0.00688)	-0.0546*** (0.0101)	0.00384 (0.00278)	0.000479 (0.00436)	0.00347 (0.00715)	0.00466 (0.00783)
CO2 emissions (log)	-0.298 (0.457)	-1.833* (1.054)	-0.613 (0.816)	-0.508 (1.207)	-0.304 (0.246)	0.0393 (0.370)	-0.442* (0.266)	-0.441* (0.232)
Governance index	0.0410 (0.123)	0.0579 (0.0728)	-0.112 (0.0957)	-0.111 (0.0994)	0.0562** (0.0251)	0.0761*** (0.0267)	0.0968* (0.0529)	-0.0762 (0.0713)
GDP per capita	0.993* (0.640)	3.718** (1.571)	0.682*** (0.058)	0.732* (0.399)	-0.108 (0.241)	-0.203 (0.264)	-1.196** (0.539)	-1.394* (0.737)
Food price vulnerability	-0.0202 (0.0194)	-0.0222* (0.0125)	-0.00508 (0.0132)	-0.00507 (0.0213)	-0.000833 (0.00335)	0.00252 (0.00172)	-0.0226* (0.0122)	-0.024*** (0.00872)
Population growth	-40.10 (28.50)	33.67 (44.40)	12.67 (64.55)	18.19 (100.1)	-15.30 (15.83)	5.742 (20.19)	-29.95** (14.67)	-32.34** (12.73)
Rural pop. growth	-0.0769* (0.0467)	-0.268* (0.144)	-0.0864*** (0.0327)	-0.0776* (0.0439)	-0.00826 (0.0109)	-0.00318 (0.0180)	-0.0966*** (0.0288)	0.0120 (0.0248)
Industrial spillovers	-2.449 (3.020)	-10.07* (5.891)	3.608*** (1.282)	3.734** (1.536)	-0.827 (0.597)	-1.063*** (0.377)	-3.169 (2.304)	-3.396 (2.230)
Services spillovers	3.248* (2.041)	9.682* (5.142)	-2.487* (1.442)	-2.691 (1.953)	0.991 (0.708)	0.621 (0.731)	2.619 (1.970)	2.847 (2.052)
Incidence of TB	-0.000272 (0.000973)	-0.00204* (0.00122)	-0.000537* (0.000291)	0.000536 (0.000361)	-0.000132 (0.000149)	-0.000110 (0.000161)	-0.000568* (0.000336)	-0.00067* (0.000384)
Prevalence of HIV	-0.0206 (0.0893)	0.292* (0.155)	-0.0441 (0.109)	-0.0290 (0.163)	-0.0319** (0.0147)	-0.0193 (0.0156)	-0.179** (0.0832)	-0.181** (0.0742)
Constant		-5.982 (9.859)		-0.159 (22.56)		0.551 (4.313)		14.34*** (5.545)
Sanit. urban, (t-1)	0.912*** (0.0324)	0.962*** (0.0353)						
Sanit. rural, (t-1)			0.905*** (0.0227)	0.903*** (0.0298)				
Water urban, (t-1)					0.996*** (0.00610)	0.912*** (0.0169)		
Water rural, (t-1)							0.945*** (0.0131)	0.946*** (0.0130)
Observations	378	406	378	406	378	406	378	406
Number of id	28	28	28	28	28	28	28	28
Instruments	18	18	17	18	14	14	14	14
AR1	0.073	0.021	0.060	0.080	0.052	0.093	0.024	0.018
AR2	0.533	0.126	0.223	0.426	0.792	0.690	0.238	0.858
Sargan OIR	0.963	0.747	0.326	0.286	0.672	0.530	0.898	0.388
Hansen OIR	0.153	0.512	0.696	0.514	0.436	0.226	0.626	0.732

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

The social dimension of agricultural sustainability implies that the proportion of food insecure populations should steadily increase. One of the greatest paradoxes of Sub-Saharan Africa is that the region holds more than 2/3 of the world's arable land, meanwhile the number of undernourished people in the region increased by 23.9% between 1994 and 2014 (FAO, 2015). A further expansion of agricultural land is also necessary to mitigate the food shortage and undernourishment effects caused by the Ukraine War.

Numerous studies have shown that various factors can affect food security such as climate variability (Affoh et al., 2022; Kinda and Badolo, 2019), climate change (Tankeu, 2021), epidemics or pandemics (Nchanji and Lutomia, 2021). Non-consensual results about the relationship between agricultural land expansion and food security justify exploration of this link. This essay fills this gap in SSA using macroeconomic data. Specifically, it investigates whether agricultural land expansion can reduce undernourishment.

Due to data availability, the study covers the period 2001–2016 and focuses on 28 countries in Sub-Saharan Africa. The essay uses a simple regression with random effects (RE) to estimate the baseline model. For robustness check, general method of moments in difference (DGMM), then in system (SGMM) techniques are mobilised.

This essay suggests that the expansion of agricultural land reduces undernutrition. This result is consistent with the literature. The reason provided here is based on the assumption of increasing returns. Primary arable land is generally more fertile than secondary land. The use of the former will require more inputs to perform agricultural activity and generate higher yields. Agricultural products prices reduce, and become more affordable to the community. Finally, it improves the access to food and reduces undernutrition, keeping other factors constant.

The secondary, arable land expansion, cereal land expansion and forest land expansion alleviate significantly undernourishment prevalence. However, permanent cropland increases exportations of crops and reduces the access to food. This increases the proportion of undernourished in Africa.

Third results in this section show that vulnerability to food prices, population growth and the shift of labour to the service sector are the main factors that increase the proportion of undernourished people. In contrast, factors such as the production index, the quality of institutions and labour movements in industry reduce the proportion of undernourished people.

To withstand the crisis, it can be recommended in the very short term that African countries identify producers, finance, promote and assist them in the use of new agricultural and arable land for both cereal and crop production.

ESSAY II
EFFECTS OF AGRICULTURAL LAND EXPANSION ON STRUCTURAL CHANGE IN
SUB-SAHARAN AFRICA

This essay has been presented at the Second Young Scholars Conference on Structural Change and Industrial Policy in Africa, organised by the South African Research Chair in Industrial Development (SARChI-ID) and Young Scholars Initiative. Conference held on between the 21–22 June 2022, at the University of Johannesburg.

And

At the Annual conference on African political economy2, ACAPE2 & Annual Conference on Regional Integration In Africa12, ACRIA12 organised by the African Political Economy Association (APEA), at the University of Nigeria , October 22-23, 2022.

1. Introduction

Structural transformation is referred to as the shift of nations from predominantly an agricultural to an industrial or services society (Bloem, 2019). Sub-Saharan Africa is the world's most agrarian continent with output and employment shares in the agricultural sector higher than in any other world region (Barrett et al., 2017; Bates and Block, 2013; Diao et al., 2017).

Despite the abundance of uncultivated land, different outcomes emerge from the debate linking agricultural growth and structural change. Firstly, agricultural land expansion neither supports structural change (Foster and Rosenzweig, 2004; Marinoudi et al., 2019; Pingali, 2007), nor reduces youth involvement in agriculture (Yeboah et al., 2019), but reduces industrial development (Rozaki, 2020). Secondly, extensive growth may increase agricultural productivity and production (Barrett et al., 2017; Caselli et al., 2012; Ngoma et al., 2021) and enhance structural change in Sub-Saharan Africa (African Center for Economic Transformation, 2017; Santangelo, 2018), with the latter constrained by little improvement in production factors (NEPAD, 2013). Thirdly, agricultural growth may have mixed effects on structural change. It supports the local non-agricultural and rural economy, through agricultural expansion, and may also crowd-out non-agricultural activity (Hornbeck and Keskin, 2011). Crop productivity growth leads to a more agrarian economy while labour productivity growth leads to an industry economy (Bustos et al., n.d.; McGowan and Vasilakis, 2019).

Several determinants of structural change include the role of governance (Totouom et al., 2019), education (Edokat and Njong, 2019), natural endowments (Mensah et al., 2016), climate change (Tankeu, 2021), labour productivity (Johnson and Vollrath, 2020), climate regions (Eberhardt and Vollrath, 2018) and conflicts or terrorism (Noubissi and Njangang, 2020).

Recent studies show that agricultural land expansion is associated with long-term economic growth (Barbier, 2020, 2021). Economic growth is inseparable from structural change (Gabardo et al., 2017). However, nothing is said about the effects of agricultural land expansion on structural change in sub-Saharan Africa, nor about the type of structural change it causes. To fill this gap, the study evaluates the effects of agricultural land expansion on the type of structural change in sub-Saharan Africa.

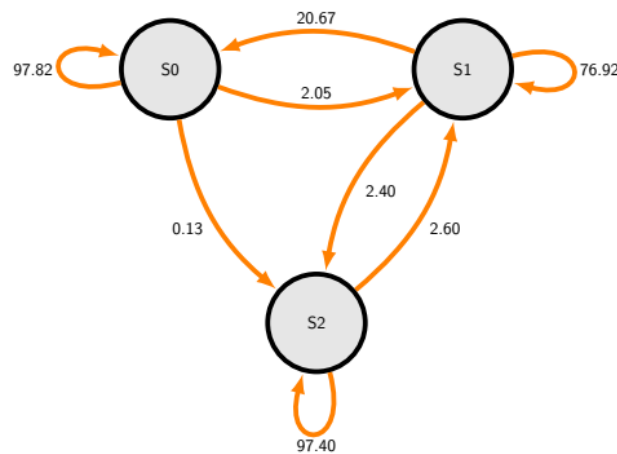
The rest of the essay is organised as follows. Section 2 presents some stylised facts on structural transformation in SSA; Section 3 discusses the literature review; Section 4 exposes the methodology; Section 5 analyses and interprets the results and Section 6 gives the conclusion.

2. Stylised facts on the structural change process in sub-Saharan Africa: A Markov Chain Analysis

This section anticipates the methodology presentation and analyses the structural change process of sub-Saharan Africa, using the built structural change variable and Markov chain analysis methodology.

2.1. Analysing the structural change process in Sub-Saharan Africa.

The following transition diagram (figure 9) provides probabilities of remaining in a particular state or moving to another state, in the next period. As the diagram shows, the highest probabilities from one year to the next are found within states: 97.8%, 77% and 97.4% for states S0, S1 and S2 respectively.



Structural Change States: S0 = Underdeveloped, S1 = Developing, S2 = Developed

Figure 9: Transition diagram of structural change, All countries

Source: author.

When countries start at the stage of structurally underdeveloped (S0), they have 97.8% chances of remaining there the next year. However, countries move from the structurally underdeveloped stage to the structurally developing stage (S1) with a probability of 2.05%, and to the structurally developed stage (S2) with a probability of 0.13%. This clearly established the idea of a structural change that ‘bypasses’ the industrial sector (Cadot et al., 2015). Countries starting at the stage of structurally developing have about 77% probability of remaining in that stage the next year. They also have greater likelihood (20.67%) of returning to structurally underdeveloped stage (S0) than move to the state of structurally development (S2) with the probability of 2.4%. This implies overall productivity decreases and confirming the idea of dynamic losses as countries go back more frequently to less productive stage S1 to S0 than the reverse (de Vries et al., 2015).

When countries are in structurally developed stage (S2) at the current period, they are almost bound, with a probability of 97.4% to remain there. The only issue is to return back to stage S1, with the

chances of 2.6% in the next period. The lowest probability of the diagram is 0.13%, on the path linking structurally underdeveloped (S0) to structurally developed (S2). It shows that, despite a possibility of reaching the (S2) state, it remains too low.

Finally, it comes out that the greatest probabilities are those of remaining in the same state. These probabilities range from 77% to 98.8% for two consecutive years. Consequently, the type of structural change is close to a time-invariant variable or process (Cameron and Trivedi, 2009).

2.2. Analysing the structural change process in sea opened countries.

The following transition graph (figure 10) is a birth/death chain. It is a Markov chain whose state space is a set of consecutive integers. It can only move from (S1) to (S2) – a birth, or from (S2) to (S1) – a death, or stay in place in one step. The graph establishes the probabilities of transitions between different stages of structural change for all countries with sea openings. It emerges that structural changes are almost immutable. So, knowing that the current year state is (S0), there is a low probability – about 3% – of moving to the (S1) state in the next year. However, it is 97% likely that a structurally underdeveloped country (S0) will remain the following year.

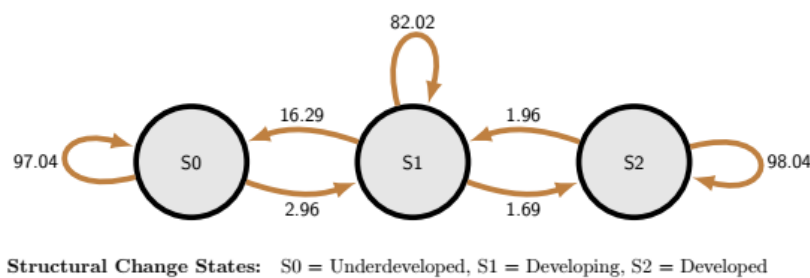


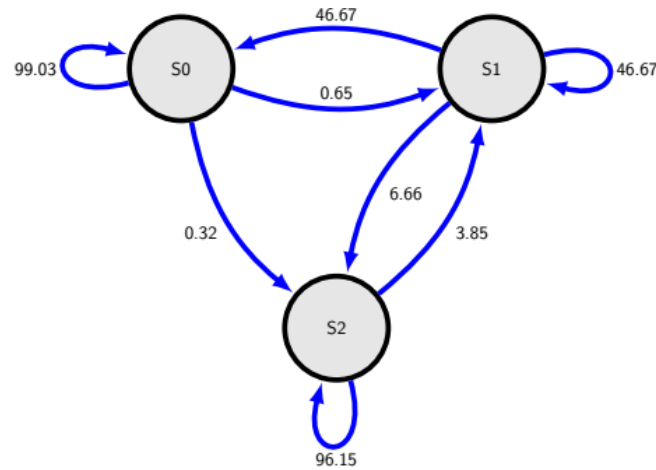
Figure 10: Transition diagram of structural change, sea cost countries
Source: author.

The same trend can be observed for countries which, in the current year, are in state (S1). In 82% of cases, they remain in the same state the following period, or they either return to the state of structurally underdeveloped (S0) with a probability of 16%, or they progress with a low chance – less than 2% – to the state of structurally developed (S2).

Countries whose state is S2 during the reference year remain 98% of the time in the same state. They have a low probability - 2% – of returning to state (S1), and a zero probability of falling, returning directly to state (S0). Additionally, the phenomenon is reciprocal, since it is impossible for countries exposed to the sea to move directly from structurally underdeveloped to structurally developed. They must therefore necessarily go through the intermediate stage S1, in line with the ‘Bypassed’ hypothesis of the industrial sector as emphasised by Cadot et al. (2015) and Baymul and Sen (2020).

2.3. Analysing the structural change process in landlocked countries.

The last transition diagram (figure 11) gives the transition probabilities for countries without an opening to the sea. It is observed that in 99% of cases, structurally underdeveloped countries do not move the following year. There is a very low probability - 0.65% and 0.32% – of progressing to stages S1 and S2 respectively.



Structural Change States: S0 = Underdeveloped, S1 = Developing, S2 = Developed

Figure 11: Transition diagram of structural change, landlocked countries
Source: author.

It is further observed that all countries at step S1 remain at this step or return to step S0 with the same probability - 46.67%. As for countries in the initial state S2, they remain at 96.15% in the same state or pass through state S1 with a probability of 3.85%.

The analysis of structural change states clearly shows that structural change cannot be sustainable in the long run. On average, countries will remain in their initial stages of structural transformation. The results are close to (CUA and OECD, 2018) findings, which claim that expected positive results of structural change are constrained as labour force move to low productivity sectors like services. Furthermore, the section highlights three major facts: First, the temporal invariability of structural change process with probabilities of remaining in the same state, from one year to another is greater than or equal to 77%; Second, structural change states are of the same class, so there is always a way out from one stage to the next; Third, the process of structural change in sub-Saharan Africa is close to a time-invariant process, because the state in which one finds oneself does not depend on the period.

3. Literature review linking agricultural land expansion and structural change

This section presents both theoretical and empirical studies linking agricultural land expansion to structural change.

3.1. Agricultural land expansion and structural change: Theoretical Frameworks

The theories linking agricultural land expansion and structural change can be subcategorised into root approach and inefficient approach.

3.1.1. The root link approach to agricultural land expansion for structural change

This approach sheds light on the expected or true links tying agricultural sector with other sectors, especially, industrial sector. Two main theories located in this approach explain the cohesion between agricultural land expansion and structural change, namely, the physiocrat theory and the Hirschman theory.

3.1.1.1. The physiocrat surplus of agriculture as a base of structural change

In his *Essay on the nature of general trade*, composed of three parts on production, money and foreign trade, Cantillon (1755) on production states that '*Land is the source or the material from which one draws wealth; the work of man is the form which produces it. Wealth in itself is nothing but the food, the conveniences and the pleasures of life.*'

This informed speculator defends land and labour as a real and objective source of wealth. If Cantillon's agricultural ideas foreshadowed those of the Physiocrats, he amended them with a very modern vision of the 'entrepreneur', reminiscent of that which would be developed by J. B. Say (1861) in the 19th century and then by Schumpeter (1981) in the 20th century. He is the one who invents this term and gives it its current meaning. Although attached to an agricultural vision of growth, he sees a specific and positive role of the entrepreneur compared to that of the ordinary peasant. The latter is often limited to repetitive work, carried out within the restrictive framework of feudal allegiances. Driven by the spirit of risk, the entrepreneur clears new land, transforms agricultural products, making wool and flax clothes pleasant to wear. He invents a world where growth is created because he dares. The entrepreneur is the economic agent who, although he is not completely certain of finding outlets, invests. It is poles apart from the world of the aristocracy, a world that lives in stagnation, a world where everyone abandons themselves to routine reinforced by social immobility.

Precursors of political economy, physiocrats like Xenophon based all economic achievements on agriculture. Physiocrats gave to land not only a leading role, but they also made it the hero of their scheme. The belief in the abundances of Nature, with rent the gift of God to the landowners, put land

in a preferred position in the *Tableau économique*. They thought that agricultural sector was central to wealth creation and economic growth.

The natural resource that is the earth, is the basis of all virtuous production which is transmitted to the entire economy. Thus, the product of the agricultural sector is based on working the land. It has the capacity to maintain a dynamic link between the agricultural sector and the industrial sector.

The leader of this school of thought, Quesnay (1758), believed that wealth comes from primitive goods such as land, people and cattle. Thus, soil fertility, associated with the work and intelligence of men and the work of animals create wealth that is greater than the needs of men. It is this excess product, referred to as overproduct or surplus, that is fundamental wealth. It is essential for both farmers and traders, or even those who operate in the manufacturing sector.

For this school of thought, the agricultural sector creates subsistence goods and the non-agricultural sector (especially industry) consumes the surplus or surplus created, or transforms it into luxury goods (Quesnay, 1758). Agriculture therefore plays a fundamental role, as food is provided by subsistence production. On the other hand, the emergence of the nation, guided by the expansion of industry, is subordinated by the productivity of the agricultural sector. Agriculture is therefore a prerequisite for the rise of a nation. The theory thus calls for the aggregation of several links and their synergy, to achieve good production performance and therefore growth.

The idea that economic growth is based on agriculture, through structural change, is from the capacity of the earth to provide a harvest greater than the seeds that the accumulation of wealth is born. Thus, developing an ambition for emergence, subsistence needs can be met through soil fertilisation using manure or chemical fertilisers, improved seeds, mechanisation or the conversion of land into agricultural land. Human work, for its part, closely resembles the strengthening of managerial capacities, for the management of industrial production, by combining the other factors of production as well as possible. Finally, animal labour, as far as it is concerned, is very close to physical capital, the good management of which requires organisational capacities of production, both at the level of the producer and at the level of the King.

To be productive, agriculture must be well managed, both in terms of policy design and in terms of practical implementation. Quesnay with his precursor theory of both structural change and growth theory, also believes that agriculture must be sufficiently organised. Each doing the best they can, in the interests of all, allow the nation to be abundant or in surplus of products. Consequently, every agent of the nation would be happy, because the net product created determines the development of

the kingdom, but the latter is constrained by that of the farmers. This is probably why he says: '*Poor peasants, poor kingdom: poor kingdom, poor king*': Quesnay (1758) in Daniel (2010).

This work tries to find a solution to the poverty of the 'kingdoms'. The poverty of Sub-Saharan Africa seems to have its roots in the poverty of African peasants. This poverty itself is due to the low subsistence and low overproduction of agriculture. Which in turn explains the weak industrial structural transformation, in favour of tertiary structural transformation. Following Quesnay, it is hypothesised that the use of land, a fundamental and sufficiently abundant input in sub-Saharan Africa, is important to increase the agricultural surplus and promote an industrial-type structural transformation.

3.1.1.2. The Hirschman structural change model and agricultural expansion

This study is rooted in Hirschman's theory of unbalanced growth, because it accounts for the forward and backward linkages that are associated with agriculture and industry relationship. The Hirschmann (1957) theory postulates an unbalanced growth model, arising from certain common characteristics exhibited by developing countries, such as low levels of Gross National Income (GNI) per capita, slow growth of GNI per capita, large inequality and widespread poverty, low levels of productivity, high dependence on agriculture, a backward industrial structure, weak consumption and low savings, high rate of population growth, high dependency ratio, high levels of underemployment and unemployment, technological backwardness and existence of both the traditional and modern sectors (dualism).

Traditional sector is the agricultural sector, which bears around 70% of the labour force. The modern sector is the industrial and service sector employing the remaining 30% of the workforce. In addition, there exists inadequate infrastructure to harness the available resources, and lack of entrepreneurs and investors to channel the cash flow through the sectors for a balanced economic growth. To this end, Hirschman proposed a deliberate unbalanced economic development strategy to maintain the existing structural imbalance, viz., complementarity, external economies and induced investment.

Hirschman unbalanced growth theory relates this study to Sub-Saharan Africa based on the need for investment in strategic sectors of the economies instead of all the sectors simultaneously. The agriculture and industrial sector in sub-Saharan have potential of generating a high level of productivity. However, since the theory assumes that the sectors would automatically develop themselves through the linkages effect, the concept of Hirschman's backward and forward linkage comes into play. The forward linkage deals with the growth of certain projects, owing to the initial growth which supplies raw materials. That is, the products produced by this industry are used as

inputs for other industries. A backward linkage is created when a project encourages investment in facilities that enable the project to succeed. Following this theory, the agricultural productivity will increase as the industrial sector will have a backward linkage with the agriculture sector by providing inputs and technologies. While, the agricultural sector will have a forward linkage with the industrial manufacturing sector by providing raw materials for processing. Therefore, expanding agricultural land will increase agricultural productivity and allow people to reallocate in the industry which promotes industrial type of structural change.

3.1.2. The inefficiency approach of agricultural land expansion for structural change

The inefficient deals with gathers theories that study the failing role of agricultural land expansion in economic dynamics. The theories exposed here are comprised of the Marxian theory of class view and the Ricardian theory.

3.1.2.1. Agricultural land expansion from the Marxian theory of class view: Landowners and structural change

In economics, land plays important roles. For Marx, the existing landlords became a unique species of capitalists of feudal vintage, but obsolete, and therefore soon to be replaced by genuine industrial capitalists. Again, land was to be cast as the unmitigated villain by Henry George, who saw it as the instrument that transfers the unearned social increment of economic progress to landlords Importance of land to productivity.

At the difference of many of his colleagues of the same generation, he did not see land as a fixed entity since the fertility of land can be affected by human labour (Marx, 1967). He thought that in the capitalist system there is an inherent tendency to decrease the fertility of land. One reason for this is the fact that most land at his time was rented by farmers, who tried to increase their return on investments before expiration of the lease, and the second reasons are the unpredictability of returns from land and the variability of nature, both of which threaten return on capital investments (Marx, 1967; Marx and Engels, 1942).

So, according to Marx, land is the channel which allows the transfer of surplus produced by the farmers to the landlords. Expanding agricultural land corresponds to increasing the way by which undue earns are transmitted to landowners. Therefore, the proportion of output produced by each of the classes, will remain unchanged no matter the amount of surplus produced by the worker class. This will encourage farmers to attempt to become landowners, which is at least unrealistic, resulting in no structural transformation. The frustrations from captured surpluses are a deep root and causes of farmers' covetousness, strikes and class fight.

He further adds that landlords are parasitic and capitalists exploitative. Consequently, their revenues in the form of rent and interest constitute distinct categories of the surplus created by farmers. Furthermore, he says ‘Rent is a product of society and not of the soil,’ to justify that even farmers should pretend to that product (Hubacek and van den Bergh, 2006). From this view, any increase will lead either to no structural change or to a bad structural change caused by conflict of classes.

3.1.2.2. The law of diminishing marginal returns in agriculture and the Ricardian doubt of structural change

Ricardo and the older English economists who followed his casting also gave to land a key role but made it the villain of the piece. The concept of the niggardliness of Nature placed landowners in a strategic position in a community with a rapidly growing population.

Ricardo (1817) is against the increase in land because the resulting increase in production is very short-lived. The productive system, as it increases production, becomes more and more inefficient: it is the law of diminishing returns. Each additional acre of land that is cultivated has a lower fertility, each peasant that is torn from his countryside to join a factory is less trained than the workers already in place and therefore less productive. Humanity is subjected to the finiteness of nature in this mechanism of diminishing returns which it tries to overcome thanks to technical progress. But this finitude is ultimately unavoidable. Humanity will reach what the Ricardian economist John Stuart Mill calls the ‘steady state’. The steady state is the moment when growth runs out and the population stabilises. The exponential can be bypassed for a while, but there comes a time when everything stops, when the limits are reached.

The Ricardian view of expanding agricultural land area is pessimistic (Daniel, 2010). Its extensive diminishing returns, suggests that many people are supposed to be farmers as lands’ production potential decreases with time. This view fits clearly with the contraction of labour force in the agricultural activities, while the other sectors are not flourishing.

Ricardo’s implicit conception of structural change has to do with technical progress. His relationship technical progress is complex. He condemns Luddits and is by nature favourable to progress. But sometimes he was seized with doubt. In his *Principles of Economy and Tax*, entitled ‘Machines’, he considers that technical progress, by substituting machines for men, makes it possible to bypass diminishing returns. In the relation to work, the economy is therefore threatened by the inability to determine a working time in accordance with productivity: by making workers work too much, there is a risk of overproduction; by not making them work enough, there is a risk of a shortage.

Here is the relationship with structural change. An important aspect is that although agricultural land expansion from technical progress leads to risk of overproduction, it is probable that it creates unemployment. Jobless people will be forced to convert into less prestigious activities and sectors, or to farm on impoverished areas, with smaller productivity, which is considered as a bad structural change.

In addition to technical progress, agricultural intensification and mechanisation, the policies recommended by the African Union (AU) to increase agricultural investments by 10% are slow to take shape in Africa. As part of this thesis, it is postulated that African countries are still far from having saturated their land availability constraints. On this basis it will be hypothesised that the increase in agricultural land generates beneficial effects for the agricultural, industrial and service sectors. The Ricardian pessimistic view maintains that the limits of the earth give humanity limits to its wealth. This view clashes with the researcher's optimistic view, according to which accumulating knowledge can break down the barrier that diminishes marginal returns from land use imposed to generate structural change.

This subsection helped to posit agricultural land expansion in the theoretical debate of structural change. Its possibility to promote structural change may depend on both the stock of arable land and the development level of countries. In a nutshell, there is a possibility that increasing agricultural land causes structural transformation in land abundant sub-Saharan Africa countries.

3.2. Agricultural expansion and structural change: Empirical literature review

There is a paucity of literature on agricultural land expansion and structural change. Studies linking agricultural land expansion and structural change, on the one hand, then studies linking agricultural intensification and structural change, on the other hand, were reviewed, followed by agricultural growth and structural transformation, to end up with other aspects of land.

3.2.1. Agricultural land expansion promoting structural change, growth and development

Torres-rojo et al. (2020) mobilises power-law models and "System for the Accountability in Fiscal Resources Dispersion" databases of Mexico to show that the density of agricultural lands and government spending to foster agriculture around a locality show a power-law relationship related to the distance from a centroid locality. The result is relevant as it shows that the expansion of the agricultural frontier around a centroid locality has a predictable dynamic, despite the complex set of social, economic, political, cultural, and physical variables which shape this expansion. Similarly, Johnson and Vollrath (2020) use Global Agro-Ecological Zone to estimate aggregate land elasticity.

Findings suggest that land elasticity influences the degree of decreasing returns to labour and capital in agriculture, and thus how sensitive living standards are to shock in productivity and population.

Xiao and Zhao (2018) investigate on the effects of agricultural land on rural-urban migration and the labour market outcomes in the context of China. Using a longitudinal household survey of 15,927 observations, they apply a Regression and Multinomial Logit Regression with the Y variable being the workers' destinations, those staying at home being the base category. They find the increased land leads to a higher propensity for migration and more land pushes people to move further. Authors also show that land affects people's time allocation between farming work, local non-farming work, and non-farming work outside their hometown. All these findings provide new understandings of the role of agricultural land in rural-urban migration in China and other developing countries. Despite the context the findings are consistent with this study's position. It is expected that more land will be a signal for people to move away from the agricultural sector, to work in the industrial sector.

Deininger and Xia (2016) try to assess evidences of spillovers from large farm establishment in Mozambique using plot-level data in Mozambique from 2002–14. Using difference-in-difference strategy, the results outline that farm establishment had short-term spillovers on neighbouring small farmers where spillover increased adoption of new practices and access to inputs. The negative spillover decreased perceived well-being. This study hypothesises that increasing land for agriculture makes the industrial sector more ready to invest in agricultural employment. Nolte and Ostermeier (2017) try to understand what effects the establishment of a large-scale farm has on the rural labour market in Kenya, Ethiopia, Nigeria, Tanzania and Uganda and whether large-scale farming creates or destroys employment. Their analysis is based on 1,346 deals of Land Matrix Global Observatory and the FAO smallholder data. It shows that agricultural expansion from foreign investments massively crowd out smallholder farmers and concludes that these effects tend to be large on the local scale (i.e. in the immediate surroundings of the investment site) but small in relation to total national employment in agriculture.

Yaro et al. (2017) analyses with model description methodology which forms of commercialisation – plantation, contract farming and medium-scale commercial farming – models will reduce impoverishment of smallholders, and transform smallholder agriculture and the wider economy in Ghana. They use data from focus group discussions and show that due to the processing units in the plantation and the outgrown models, they provided more employment but less food insecurity.

Santangelo (2018) studies the influence of large-scale farms captured by foreign direct investments (FDI) in land, in agriculture in both developed and developing countries, on host country structural change. Results from this conditional mix process model suggest positive spillovers or structural

change for developed countries and negative structural change for developing countries. Applying his mapping methodology Sauer (2018) shows with extensification can promote the creation of agribusiness enterprises – like in Brazil, but can also cause territorial disputes which discourages and impacts social harmony.

In northern Sierra Leone, Yengoh and Armah (2015) apply both quantitative and qualitative research methods on 442 households. Parametric and non-parametric mean tests show that because of land acquisition, employment by the land investing company is limited in terms of the number of people it employs relative to the population of communities in which it operates. Also, wages from employment by the company cannot meet the staple food needs of its employees, which pushes population to move to other sectors. Moreover, Nyantakyi-Frimpong and Kerr (2017) try to account for impacts LSLA on food security of 155 households in Ghana. Applying comparison methodologies, they find that land grabbing exacerbates food insecurity, decreases job opportunities, increases social conflicts, sparks migration in host country.

According to Mensah et al. (2016) show using system generalized method of moments on 21 countries in SSA over the period 1970–2012, that increasing land for agriculture will lead to an improvement of industrial, manufacturing and service value-added shares in African countries. However, they fail to see structural transformation as the labour movement, which characterises the most sub-Saharan African countries. What this work intends to do.

Barbier (2020, 2021) shows that agricultural land expansion is linked to economic growth, in 97 low and middle-income countries. He uses in 2020 both quadratic and cubic models estimated with random and fixed effects and find that expanding land has been an engine of growth in developing economies. Similarly, in 2021 he draws the same conclusion using Solow-Swan model over 1990–2018 for 138 low- and middle-income countries (Barbier, 2021). The same relationship is identified as a secondary result, while studying the Nepalese economy from 1970 to 2015 and using an autoregressive distributed lagged model (Ghimire et al., 2021).

3.2.2. Agricultural intensification

Foster and Rosenzweig (2004) use a series of household data sets from India covering the period 1971–99 to measure how agricultural development affects the composition of rural activities and incomes. Growth in income from the nonfarm sector in rural India over the last 30 years has been substantial, and the primary source of this growth, is the expansion of rural industry, rather than the expansion of local agricultural productivity. The study used a Laspeyres-weighted (1971) price index for four High-Yield Variety seeds for four crops – corn, rice, sorghum, and wheat, to capture

agricultural change. It deals with intensification rather than extensification of agriculture. The present study, however, seeks to analyse if the agricultural land expansion is a good option for structural change in Africa.

Hornbeck and Keskin (2011) analyse whether windfall agricultural gains in United States countries generate local economic spillovers in both the short and long term. Using econometric model on cross-sectional pooled data, they find that agricultural productivity promotes structural change in the short run. Comparing counties over the Ogallala with similar counties, non-agricultural sectors experienced only short-run relative benefits. There was no long-run relative expansion in Ogallala counties' nonagricultural economic activity. However, the study analyses how agricultural expansion promotes economic spillovers from agriculture, irrespectively to the runs. It expects that expansion of agriculture in SSA, be able to generate benefits to the industrial sector.

McGowan and Vasilakis (2019) study how productivity-enhancing agricultural technology affects structural change. Applying a difference-in-difference estimation strategy, they conclude that technology improves land productivity and increase the concentration of economic activity in the agriculture. They reach the conclusion that technologies which raised crop productivity led to a less urbanised economy as economic activity relocates from manufacturing and services towards agriculture. In other words, agricultural growth, as a result of intensification made the economy be more agrarian. This is true if the technology necessitates increased agricultural labour demand.

In Brazil, Bustos et al. (2016) study the adoption of new technologies on structural transformation. Authors present a simple model where the effect of agricultural productivity on industrial development varies according to the factor bias of technical change. They found that the effects of agricultural productivity on structural change depends on whether crop productivity or agricultural labour productivity increases. The former leads to a more agrarian economy while the latter is favourable to a less agrarian economy. They find that technical change in soy production was strongly labour-saving and led to industrial growth in Brazil.

There is also a strand of literature which argues that agricultural productivity may not always enhance structural transformation. For instance, studies in Brazil and the United States of Bustos et al. (2016) and McGowan and Vasilakis (2019) respectively, show that in an open economy the agricultural productivity and structural change linkages rely on the factor bias of the productivity shock. Clearly, on one hand, improvements in agricultural labour productivity (output per worker) reduce agricultural labour requirements, leading to an expansion of industry as workers relocate to manufacturing. On the other hand, increase in land productivity (output per acre) raises agricultural labour demand as a greater number of workers are required to process the additional output. In equilibrium, this bids up

wages leading to factor reallocation as manufacturing workers transition to employment in agriculture. This makes economy be more agriculture-oriented and less industrialised.

Binswanger-Mkhize and d'Souza (2012) analyse the structural transformation of the Indian economy and its agriculture. They decompose total factor productivity and find that although the agricultural share of gross domestic product (GDP) plunged between the early 1960s and the late 2000s, it remained the main employment sector throughout the period as in Sub-Saharan African countries. The authors conclude that growth of the agricultural sector, and productivity growth in particular, should be accelerated for India to generate sufficient new employment for its burgeoning rural population. In accordance with their study, it is expected that increasing agricultural land can provoke productivity shocks and structural transformation. Thus, still in line with the study, it is hypothesised that increasing productivity will generate more employment in the industrial sector for outflows of agriculture labour force.

Gasques et al. (2012) analyse the TFP growth and structural transformation in Brazil. They capture structural transformation by using the agricultural census between years 1970 and 2006, they find that productivity growth was the major driver of growth in Brazilian agriculture. They estimate a 2.1% per annum TFP growth rate for the whole period, with accelerating TFP growth over time. Moreover, they find more varieties of output in the agricultural production and hold that this diversification can have advantageous effects on employment as farmers allocate production factors to higher valued products. Following this study, one assumes that increasing land may allow producers to increase the varieties of species to be produced and will create new types of employment and may lead to structural transformation.

In his dissertation thesis, McCullough (2017) explores the link between labour productivity and the occupational choice that underlies the structural transformation process. He draws a model of households' decisions to participate in various activities like farming, wage employment, and self-employment – through operation of a household nonfarm enterprise. He finds that participation in farming is not responsive to productivity shocks of any sort. However, wage employment and self-employment participation do respond to wage and self-employment shocks of productivity, respectively. This study is conceptually close to his, only few differences can be made: This uses a macroeconomic analysis, and one thinks that land productivity shock could increase the probability of labour force to locate in the industrial sector, but less in the service sector.

Using a two-sector model economy, and general equilibrium analysis, Chen and Liao B.-L. Chen and Liao (2015) find that in the long run, growth in agricultural productivity increases nonagricultural capital and decreases agricultural capital and, through the complementarity between labour and

capital, it eventually causes a negligible agricultural employment share. Then, authors find that in the model with capital in both sectors, agricultural productivity growth can generate structural change that matches reasonably well with the data; meanwhile non-agricultural productivity growth cannot. They finally conclude that, in richest countries, growth in agricultural productivity is crucial to governing long-term and massive structural change. In a similar way, for developing countries, agricultural productivity provoked by land expansion for crop production purposes can lead to massive reallocation in the non-agricultural sector. In the context of sub-Saharan Africa, the agricultural land expansion may cause inflow of labour force in the industrial sector, more than in the service sector.

Zhang and Diao (2020) use China's case to assess implication of structural change to the evolving role of agriculture. By combining a twofold growth decomposition exercise with Input-Output (IO) and CGE model analyses, the analysis shows that the direct contribution of productivity growth within agricultural sector to the broad economic growth is impressively high in China. Although the contribution remains significant, becomes modest because of rapid falling of agricultural shares in the economy and total employment. Rising labour productivity in agriculture has led to rapid agricultural growth without increasing agricultural employment. This allows agriculture to indirectly contribute to the economywide productivity growth through structural change, confirming the arguments of many development economists who emphasise the impact of agriculture on structural change in the relationship between agriculture and structural change.

Marinoudi et al. (2019) assess the theoretical links of robotics and labour in agriculture in the short and mid-term. Author's claim that standardised tasks executed by machines increase labour productivity and drives out labour from the sector. Meanwhile, non-standardised tasks executed by robotics and artificial intelligence, are expected to have a mitigated effect on labour share in the agricultural sector. Low-skill labour (offering routine tasks) is to be substituted (the substitution effect) while, high-skill labour (cooperation in cognitive tasks) is to be complemented (the complementarity effect).

With her specific features, Africa has been an abandoned case by such studies. This study proposes to fill that gap and in accordance with their results, thinks that agriculture growth can also promote industrial reallocation change in sub-Saharan Africa region.

3.2.3. Agricultural growth as determinant of structural change

There is a long tradition in economics of studying the links between agricultural productivity and industrial development. Nurkse (1953), Schultz (1953) and Rostow (1960) argued that agricultural

productivity growth was an essential precondition for the Industrial Revolution. Classical models of structural transformation formalised their ideas by proposing two main mechanisms through which agricultural productivity can speed up industrial growth in closed economies. (i) First, the demand channel: agricultural productivity growth rises income per capita, which generates demand for manufacturing goods if preferences are non-homothetic (Gollin et al., 2002). The higher relative demand for manufactures generates a reallocation of labour away from agriculture. (ii) Second, the supply channel: if productivity growth in agriculture is faster than in manufacturing and these goods are complements in consumption, then the relative demand for agriculture does not grow as fast as productivity and labour reallocates towards manufacturing (Baumol, 1967; Ngai and Pissarides, 2007).

The view that agricultural productivity can generate manufacturing growth was challenged by scholars studying industrialisation experiences in open economies. These scholars argued that high agricultural productivity can retard industrial growth as labour reallocates towards the comparative advantage sector (Field, 1978; Mokyr, 1976; Wright, 1979). Their ideas were formalised by Matsuyama (1992) who showed that the demand and supply channels are not operative in a small open economy that faces a perfectly elastic demand for both goods at world prices. The open economy model presented in this essay differs from Matsuyama in one key dimension. In his model, there is only one input to production thus technical change is, by definition, Hicks-neutral. Bustos et al. (2016) models consider two complementary factors, land and labour in agricultural production. Thus, technical change can be factor-biased. From that setting, a new prediction emerges: when technical change is labour augmenting, an increase in agricultural productivity leads to a reallocation of labour towards the industrial sector even in open economies. This study instead tries to link reallocation of labour across sectors to agricultural land expansion. If the previous studies have analysed how intensification of agriculture can affect structural change in developed countries, less evidence is known about the relationship between agricultural expansion and structural transformation in Africa south of the Sahara.

3.2.4. Other aspects of land expansion and structural change, growth and development

This subsection reviews studies and discusses the characteristics of land and land tenure that are important to productivity. It focuses on John Mellor (2017), which addresses many aspects of the links between structural transformation and agricultural land.

3.2.4.1. Land productivity: the traditional versus the modern context

Land productivity is characterised by a high variability around a low yield average, in the traditional context (Mellor, 2017). Moreover, combinations of labour leisure for a low – productivity function of

production, will not increase land productivity. If this is the case, it will cause the number of people to stick at high levels. However, with modernisation, production possibility curve moves outward, and combination of labour-leisure yields higher quantities, and production variability drops. Thus, countries that have engaged agricultural modernisation will see higher productivity. This is what is expected for Africa. Despite African countries have not yet completely modernise their agriculture, some efforts are being made. On this process, increasing land areas will allow unused labour to relocate in other sectors thus creating structural change.

3.2.4.2. Fragmentation of Farms

There is a common problem of farm fragmentation in Africa – that means a division into many small parts, often quite distant from each other (Mellor, 2017). Land is generally transmitted from previous generations to the next generations. Then, fragmentation arises partly from the complexity of generations of inheritance, and occasionally from small purchases. Although fragmentation has the advantage of diversifying risk-cutting across different soils and even rainfall regimes in a traditional agriculture, it reduces chances of either economy of scale or high production. In Africa, 80% of the smallholder have farm size less than 2 ha (Masere and Worth, 2022; Ncoyini et al., 2022). This can explain high number of people still in the agricultural sector.

However, with modernisation, especially the tapping of ground water on a small scale, and to some extent with machinery and for marketing purposes, consolidating land holdings has a major advantage. This thesis assumes that land expansion for agricultural purposes, that means consolidating lands and allowing productive farmers to get land, could help to generate agricultural outflows of labour. This can be done with government intervention that may be necessary to reconcile local differences on whether and how to proceed.

3.2.4.3. Land registration

Africa is rooted in his ancestral culture. Corollary, land ownership is commonly legitimised by tradition rather than legal registration and documentation. Feder and Nishio (1998) expose that it is beneficial to development that land markets with land registration have well-working, as modernisation goes on. They even argue that it is strongly desirable. According to Mellor (2017), in a traditional agriculture and in early stages of modernisation, premature registration of land and consequent formal title may simply strengthen those who would like to dispossess weaker members of the community. In a situation of domination by a tribal chief, the less scrupulous may allocate land to themselves and seal the transfer with registration. It may also strengthen corrupt elements in government who could seize land and register it in their own names before the weaker members in the community can respond. The work supposes that in that stage where African countries are still in

the process of land registration, increase of secured agricultural land will help structural transformation to occur.

Given the importance of land as a storehouse of wealth in low- and middle-income countries, it is better to develop open, well-operating, rental market than the market for sales. The most important feature of a well-functioning rental market is security of ownership in the face of land being operated for years by another.

3.2.4.4. Land tenure

The analysis of Deininger et al. (2017) suggests that land markets are more active and have potential to contribute to structural transformation in Africa than commonly assumed. Using micro-level data sets of six countries (Ethiopia, Malawi, Niger, Nigeria, Tanzania and Uganda), authors conclude that, despite the expected low potential of land rental in the countries, great differences in land endowments and productivity generate potential for land markets to equalise endowments and contribute to higher levels of productivity. In addition, authors suggest that land rental markets build more equity by promoting land access to those with limited land endowments, and increase productivity.

This study enlightens the relationship between land and structural change in Africa. Two outcomes are possible. Agricultural land expansion may create structural change by increasing productivity of farmers. But conversely, it may reduce the process of structural change if rental land market performs bad. That means the insecurity of tenure reduces farmers' devotion to their production activity. While carrying this macroeconomics analysis, it is expected that improvements accomplished in the land tenure domain, can allow land expansion in Africa to cause structural change.

3.2.4.5. Small – Commercial Farms, large scale farms and plantations

African's agriculture is dominated by small commercial farms and great inequalities among them. Mellor (2017) holds that there is little or no evidence of political processes that would reduce that inequality or distribute land to those with little or no land. Moreover, he claims that such efforts would be counter-productive in the context of growth.

In some parts of Africa, vast areas are devoted to large commercial farms and plantations, which are simply large-scale commercial farms producing tropical export commodities. These were mainly the product of colonial systems that were reinforced by the special conditions of tropical export commodities, particularly the need for quality control and conglomeration for export, and the high level of profitability for colonial owners. Although large-scale farms are productive as they have

access to modern technology and inputs (Deininger and Byerlee, 2012) they fail to support local, rural nonfarm population activities.

We assume that, land expansion and government intervention can generate help to generate more output. Some governments in Africa imposed that, transformation of part of their agricultural products takes place within countries, as it is the case in Ivory Coast for cocoa. Such type of policy if implemented will benefit to local non-agricultural communities.

3.2.4.6. Increasing land area and agricultural productivity with respect to population density

In densely populated countries like Ethiopia, for more than 20 years, increased land accounted for about 40 percent of the rapid agricultural growth rate (Mellor 2017). Clearly, small technological change brings increased returns to land, covering the costs of bringing additional land into cultivation. Concurrently, a change in attitudes and availability of consumer tastes for goods increases the value of the output of labour relative to leisure. Even though land is limited, increased land area will add to the growth for a short period, as shown by India and Ethiopia, perhaps for a decade or somewhat more (Mellor, 2017).

Conversely the situation in low population density areas is very different to that in high population density areas. Generally, such areas are dry and inhabited sparsely by semi-nomadic families relying on cattle herding for the bulk of their income. In other cases, their use may be restricted, by disease as in some areas of West Africa. While having high potential of productivity, these lands tend to require significant investment in roads and irrigation systems. Then developing it may be highly profitable. This fits the particular case of East Africa. If so, it should cover all its costs, leaving public investment for the high-potential, densely populated areas.

The link with the present study is clear. In the case that land expansion for agriculture is followed by land fragmentation, the economy will be more agrarian and structural change may not happen. However, if agricultural land expansion conducts to more investments into large-scale farms, it is expected to cause agricultural productivity and then structural transformation. This point is in line with the study's position.

Some studies (Edokat and Njong, 2019 and Totouom et al., 2019) identify institutional quality and governance as determinants of structural change. For this reason, the study incorporates the quality of institutions which is the best way of capturing government intervention in social studies. Following these studies, it is theorised that good quality of institutions is more likely to sustain structural

transformation towards industry and terms like institutional quality and governance interchangeably are used.

Concerning trade openness, dependence on primary commodity exports is associated with lower labour productivity in SSA (Kaba et al., 2022; Kacou et al., 2022). In SSA, however, manufacturing exports positively impact structural change (Kaba et al., 2022).

4. Methodology of analysis of the effects of land expansion on structural change

This section of the study presents the methodology to assess the effects of agricultural land expansion on structural change in sub-Saharan Africa. It starts by a general presentation of data and variables, followed by a presentation of our descriptive statistic. Last but not least, we expose the estimation strategy.

4.1. Data, sources and variable construction

This subsection provides information on the data and scope of the study. It also provides construction and justification of variables retained in the model, tools used to describe links and stationarity tests.

4.1.1. Data and Data sources

The essay seeks to assess the effects of agricultural expansion on the type of structural change process. All data used come from the World Development Indicators (WDI, 2021) except the Governance and Institutional variables coming from the World Governance Indicator (WGI, 2021).

The WDI database provides datasets on structural change for the majority of countries of the scope of interest. It also supplies the interest variable agricultural land, cereal land and permanent crop land and many other variables used in this study including population, per capita Gross domestic product, value added of different sectors. These variables are detailed more in the next subsection.

As mentioned in the first essay, the WGI database has the advantage of containing six variables measuring the quality of political institutions since 1996. These values range from around -2.5 (worst institutional quality) to 2.5 (best institutional quality). The WGI database covers a wider range of countries and territories (200 precisely) than the International Country Risk Guide (ICRG), which only involves 140 countries, and the Polity IV database, which only concerns 167 countries. The Principal Component Analysis (PCA) is used to build a composite measure of institutional quality. This composite index is calculated by applying the PCA to the following six variables: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government's Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

The sample is constituted of 41 sub-Saharan African countries, of which 27 and 14 are sea opened and landlocked countries respectively. The panel is a strongly balanced. The period of the analysis is from 1990 to 2016 owed to the availability of entries in the model variables. The period and sample are dictated by the availability of relevant data. While some variables are raw, others are constructed according to literature of their respective fields. It is the case for the dependent variable *type of structural change* (TSC) and for the regressor *governance* (Gov).

4.1.2. Construction of variables

Both variables of structural change and the governance index are constructed.

4.1.2.1. Building the variable type of structural change

Literature provides many ways of measuring the structural change: some authors use shares of value added of economic sectors (Syrquin, 1988), others use in addition, employment shares of each sector and final consumption expenditures (Herrendorf et al., 2014). The main limitation of these structural change indicators is that they do not provide an overall amplitude of the structural change phenomenon as for Norm Absolute Value (NAV) and the Modified Lilien Index (MLI) (Dietrich, 2012). Productivity decomposition methods are also used to capture the structural change effect on growth which they call dynamic structural change (de Vries et al., 2015; Fagerberg, 2000) by the first ones who use a threefold decomposition. On the other hand, there is a twofold decomposition (Diao et al., 2017; McMillan et al., 2014; McMillan and Rodrik, 2011) which does not distinguish between static and dynamic structural change as the change itself is obviously a dynamic process. Another measure of structural change uses simultaneously, the Norm Absolute Value and the twofold decomposition method (Vu, 2017). Baymul and Sen (2020) consider the twofold decomposition, the country's incomes level and the size of employment shares in different sectors to categorise structural change types at the time of their analysis. The present study mobilises a similar methodology to build a comprehensive indicator of the overall structural change for each period of time.

According to Baymul and Sen (2020), countries can fall under the following three main stages of structural transformation: First of all, the set of countries where the proportion of workers in agriculture is higher than any other sector for the most recent period for which the data are qualified as countries *structurally underdeveloped*. Then the set of countries for which the percentage of labour force in services is greater than that in agriculture, though the share of workers in agriculture is still greater than that in manufacturing is referred to as countries *structurally developing* experiencing a services-driven structural change. Finally, countries where the share of workers in manufacturing is greater than that in agriculture. This set of countries is called *structurally developed* countries undergoing manufacturing-driven structural change.

Following Baymul and Sen (2020), we code the dependent variable as follows:

$$TSC = \begin{cases} 0 = \text{Structurally Underdeveloped if } agrsh > indsh \text{ and } agrsh > scesh \\ 1 = \text{Structurally Developing if } scesh \geq agrsh \text{ and } agrsh > indsh \\ 2 = \text{Structurally Developed if } indsh > agrsh \end{cases}$$

Where *agrsh*, *indsh* and *scesh* represent the proportion of agricultural, industrial and service labour force respectively, in the total employment.

To simplify the following nomenclature can be adopted: Consider that agrarian countries have $TSC = 0$, countries bypassing the secondary sector have a ‘services-oriented’ structural change and corresponds $TSC = 1$; Finally, countries qualified as structurally developed are following an ‘industrial – oriented’ structural change (Baymul and Sen, 2020; Hölzl, 2021).

Although this codification of the dependent does not want to establish a superiority between modalities, it presents a threefold advantage. Firstly, one can observe the country shares of different sectors at each point of time and identify the type of structural change. Secondly, it enables one to analyse the dynamics or transitions from one type of structural transformation to the other. It also enables one to appreciate if the structural change process is time invariant or not. Clearly, it means to identify if the states of structural change are likely to last for long or not. Third, this model can identify which type of structural change countries are likely to undergo after being structurally underdeveloped. Moreover, one may know which variable contributes to the ‘bypass’ of the secondary sector, and which one promotes the industrial oriented of structural change.

4.1.2.2. Building the Governance index

The construction of the Governance index is intentionally omitted in this essay. The institutional variable in this essay is the governance index. Its construction is described in the first essay of this thesis.

4.2. Descriptive statistics

4.2.1. Markov chain analysis of the structural change

The study analyses how the structural change variable varies over both time and countries. Variation over time for a given country is called within variation, and variation across countries are called between variation. This distinction is important because estimators differ in their use of within and between variation. In particular, in the FE model the coefficient of a regressor with little within variation will be imprecisely estimated and will not be identified if there is no within variation at all. A time-invariant variable will have a within percent of 100 (Cameron and Trivedi, 2009).

4.2.1.1. Transition probabilities

According to Markov Chain Analysis, the three modalities of response variables are states. Working with cross-sectional and time series data, allows calculation of transition probabilities from one stage to the other, and from one period to the next. It suits with a Markov chain process.

A Markov process or chain consists of a sequence of repeated trials of an experiment whose outcomes have the following two properties (Lipschutz and Lipson, 2011):

- Each outcome belongs to a finite set $\{S_1, S_2, \dots, S_n\}$ called the state space of the system; if the outcome on the n th trial is S_i , then it is said that the system is in state S_i at time n or at the n th step.
- The outcome of any trial depends, at most, on the outcome of the preceding trial and not on any other previous outcome.

Accordingly, with each pair of states (S_i, S_j) , there is given probability p_{ij} that S_j occurs immediately after S_i occurs. The probabilities p_{ij} form the following n -square matrix:

$$\mathbf{M} = \begin{bmatrix} p_{11} & \cdots & p_{1n} \\ \vdots & p_{ij} & \vdots \\ p_{n1} & \cdots & p_{nn} \end{bmatrix}$$

Where matrix M is a stochastic matrix, and regular in this case, called the transition matrix of the Markov process. For each state S_i there corresponds the i th row $[p_{i1}, p_{i2}, \dots, p_{in}]$ of the transition matrix M . Moreover, if the system is in state S_i , then this row represents the probabilities of all the possible outcomes of the next trial and so it is a probability vector. As applied to this study, the fixed lines represent the probability of being in one stage (Structurally Underdeveloped for example) and moving to any other stage through sectoral dynamics.

The fundamental hypothesis here is that the future stage (Y_{t+1}) depends only on the current stage (Y_t). For time-invariant data, the diagonal entries will be 100% and the off-diagonal entries will be 0%. The diagram of transition probabilities is drawn for landlocked countries and for open (sea) countries.

4.2.1.2. Graphics of transition

Thanks to the calculation of transition probabilities one can draw graphs clearly showing the transitions from one step to the other. To provide a detailed analysis, three transition graphs were produced: The first gives the transitions for the overall sample, the second focuses on the countries that are open to the sea, and the third shows the state transitions of landlocked countries.

4.2.2. Graphical analysis of variables

The descriptive statistics give the broad features of variables and their stationarity level on the one hand. Then, the graphical disclosure of land expansion paths is used in sub-Saharan Africa, and finally, a link between labour displacements with respect to agricultural land expansion. The latter is done by using scatterplots for within and between variation. After these presentations of preliminary relationships, an econometric estimation of the model is made.

4.3. Estimation strategy

The estimation strategy displays the model to be estimated and estimation techniques, the justification and expected relations and the interpretation of the coefficients of the model.

4.3.1. Baseline model and estimation techniques

The baseline statistical model takes the following form

$$Y_{it} = \alpha_0 + \alpha_1 \text{aland}_{it} + \beta_2 X_{it} + \varepsilon_{it} \quad (\text{eq7})$$

Where α_0, α_1 and β , are the vectors of parameters to estimate. ε is the error term following hypothetically a multinomial logistic distribution. Y_{it} is the categorical dependent variable capturing structural change with three categories as described in the construction subsection. The variable aland_{it} is the variable of interest capturing the agricultural land expansion. X_{it} is the set of control variables, including governance, the sea openness status, the population growth, and other variables as justified in subsequent paragraphs.

The statistical model of the study is estimated with a fixed effects estimator. However, to perform this estimation on this type of discrete polytomous dependent variables, no statistical software is yet available (Allison, 2009). Different options remain available for this type of regression with such dependent variables. For example, Pooled Multinomial Logistic (POMLOGIT), Random Effects Multinomial Logistic Regression (REMLOGIT) (Rabe-Hesketh and Skrondal, 2012; Wooldridge, 2010). Both estimation techniques are used.

For the first model, the Pooled Multinomial Logit (POMLOGIT), panel – robust standard errors are used to account for plausible time correlation across waves. The verb ‘pool’ means to combine or merge things. Consequently, econometricians talk about the combined data of all individuals in all periods as a pooled sample. Then the regression equation is a pooled model and if one applies OLS to this pooled model it is called pooled least square, or pooled OLS. As well, if an MNL is applied to the pooled model, it is named Pooled Multinomial Logit (POMLOGIT).

The second model is fitted with `gsem` Stata command, as described in [SEM] example 41g of the Stata Manual (Pfarr, 2014). The Pooled Multinomial Model is estimated, and robustness is checked with the estimates of the multinomial random-effects logit (REMLOGIT). The latent variable for countries means constant within countries and vary across countries. Two latent variables are used to capture countries effect to yield random effects.

The third model is estimated with fixed effects estimators, which is a user-written STATA command. The model offers the possibility to control for unobserved heterogeneity, which makes these models a prime tool for causal analysis. Using such estimators is constrained by many computation problems and convergence problems as well. This occurs, like in the present study's case, when the period is high.

'... This means that computation time increases with the number of permutations in the dependent variable. In practice, this will rise with T_i . The computation time can be very high, even if T_i is large for only a small subset of individuals $i = 1, \dots, N$. If computation becomes unwieldy, a random subset of available measurements of all observation units should be analysed.' (Pfarr, 2014).

Following Pfarr suggestion, the sample from the 2004–2016 period is analysed, which is randomly determined.

The study's statistical model can be estimated with a fixed-effect estimator. Indeed, for polytomous discrete dependent variables, no statistical software package is available yet (Allison, 2009). Various options remain available for this type of regression with such dependent variables. For instance, the pooled multinomial logistic or probit regression and the multinomial logistic or probit regression with random effects (Rabe-Hesketh and Skrondal, 2012; Wooldridge, 2010). For both models, it must be assumed that any unobserved heterogeneity is independent of the observed covariates, which is not always true (Pfarr, 2014). A multinomial logit with fixed effects (FEMLOGIT) helps control for unobserved heterogeneity (Pfarr, 2017) and is used as a robustness check.

Two reasons justify that neither the Hausman test nor the Likelihood Ratio (LR) test to choose the best estimators are performed. The first reason is methodological; when the robust option is applied while running our commands, it disables the researcher to perform the Hausman and LR tests as the variances are robust and modified (Stata Manual 14). The second reason is conceptual: this essay shows that agricultural expansion promotes an industrial type of structural transformation. Achieving this aim more important than making estimators compete.

4.3.2. Justification of variables in the model and expected type of structural change

The introduction of a lagged dependent ($y_{i,t-1}$) variable is intuitive, as the type of structural change of the current period ($y_{i,t}$) could certainly be explained by the last year structural change type ($y_{i,t-1}$) in equation (1). Thus, the effects of X, Z and T are estimated controlling for the former status of the unit. However, methods for these kinds of dynamic models, are not readily available for categorical data (Long and Freese, 2001, 2014).

Agricultural land refers to the share of land area that is arable⁵, under permanent crops, and under permanent pastures. Arable land accounts for the cross-country differences in real output of the industrial sector. It is measured as a percentage of total area. Similarly, arable land is a significant factor determining real value added of the sector (Mensah et al., 2016). With an extended Solow-Swan model, Barbier (2020) indicates that land expansion boosts growth, and this effect increases with the relative share of land in income. This essay shows that agricultural expansion is more likely to make a country structurally developed than structural developing.

Agricultural land per capita (*arlandcap*): The concentration of population (rural or urban) on land is essentially a barometer of economy-wide development (Barbier, 2004b). Where there is abundant marginal land for cultivation, it can absorb rural migrants, extra population, and displaced unskilled labour from elsewhere in the economy. However, the per capita area of agricultural land declined from 0.55 ha in 1961 to 0.23 ha in 2009 (FAOSTAT, 2013), leading to a fall in agricultural output, then may lead countries to shift from an industrial or service economy.

Gross Domestic Product is included in the equation as a log. It is found in the literature that the economic growth increases the real value added of manufacturing (Totouom et al., 2019; Mensah et al., 2016) and the real value added of the service sector, with a weaker effect on the latter sector (Mensah et al., 2016). From the researcher's point of view, economic growth is more likely to lead economies to a tertiary stage than to an industrialised economy stage, as the tertiary sector has similar characteristics to the agricultural sector.

The variable population growth was included in the model to determine how demographic changes affect structural changes. There are evidences that population size increases the value-added share in the industrial sector (Totouom et al., 2019), increases the service sector real product and reduces agricultural value added (Mensah et al., 2016). However, the agricultural sector is still important for

⁵ Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow.

sub-Saharan countries to an extent that, an increase in the population growth will result to a more agrarian economy (Tankeu, 2021).

The quality of institutions, captured by the variable governance (*gov*) has a major role in promoting structural change. As developed by many authors (Edokat and Njong, 2019; Totouom et al., 2019), promoting structural transformation requires better institutional qualities. Henceforth, good governance is expected to spur an industrial type of structural transformation.

To determine whether structural change depends on international trade, the variable trade was used in the model. The literature identifies reduction in trade barriers as a factor not only promoting growth, but also leading to structural change (Mallick, 2017; Roy and Roy, 2017). In Africa, it has contributed to a boom in the service sector (Mensah et al., 2016). The variable trade is expected to lead countries at the structurally developing stage.

Being a landlocked country can slow process of structural change due to the high transportation costs. Some scholars argue that the location of countries, and essentially whether they are landlocked or opened to sea determines their ability to grow and transform their production structures (Collier, 2008; Faye et al., 2004; Sachs et al., 2004). The variable *sea coast* (with '1' for *landlocked* countries) is inserted into the model and it is expected that landlocked countries have lower chances of engaging in structural development than sea coast countries.

International trade openness is proxied and included in the model by the variable *trade* as a percentage of GDP. Barbier (2021), holds that economic growth is accelerated by trade. It is expected that *trade* variable favors 'services – type' of structural change than underdeveloped type of structural change.

Following Barbier (2021), the interaction variables of population and agricultural value added in real terms (*popgXagva*) and the variables agricultural land expansion and agricultural real value added (*aglXva*) are introduced in the model. The former enables the investigation of the combined role of population growth and agricultural growth on structural change, while the latter explains how both agricultural land expansion and value-added influences the structural change processes.

African countries are often reliant on their natural resources. Thus, just as Mensah et al. (2016), the regressor mineral rent was introduced as a percentage of GDP, as a proxy for mineral (*mineral*) resource endowment. The variable will help analyse the structural effects of natural endowments. The variable is expected to have a positive effect on 'industrial-type' of structural change.

Finally, the variable permanent crop land is introduced as a percentage of land area. It helps to assess the importance of permanent cropping on type of structural change in Africa. According to FAO

(2019), permanent cropland is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber. It is expected that the variable will increase the probability of countries being structurally developed, as the crops produced are inputs for agribusiness industries and trade.

The expected relationships of variables with the type of structural change are summarised in table 11.

Table 11: Variables and expected type of structural transformation

		Structurally Developing	Structurally Developed
aland	Agricultural land		+
arlandcap	Agricultural land per capita		+
Gov	Governance		+
Trade	International trade openness	+	
minerent	Mineral rent		+
popgXagva	Population and agricultural value added		+
aglXva	Agricultural land and value added		+
lngdpcap	Gross domestic product	+	
Popg	Population growth	+	
Pland	Permanent crop land		+
1 if landlocked	Landlocked country	+/-	+/-

Source: author.

Coefficients of the variables of a multinomial logit model with the interpretation need some explanations.

4.3.3. Interpretation of the parameters of the model

Care is needed in the interpretation of parameters in any nonlinear model. This is particularly true for multinomial models where, for example, there is not necessarily a one-to-one correspondence between coefficient sign and coefficient probability (Cameron and Trivedi, 2009) The negative sign does not mean that the increase of the regressor value will reduce the explained variable. For the MNL model, the comparison is to a base category, which is the alternative normalised to have coefficients equal to zero.

For economists, it is more natural to interpret β_j as **semi-elasticity**. Then, taking a calculus approach, a logit model slope parameter of 0.1 is interpreted as meaning that a one-unit increase in the regressor increases the odds ratio by a multiple 0.1. This coincides exactly with the interpretation used in statistics for very small β_j , since then $\exp(\beta_j) - 1 = \beta_j$.

Another useful interpretive device is the probability ratio or relative risk ratio. It shows how many times more likely category j is to be chosen relative to the first category.

$$\frac{P(y_i = j)}{P(y_i = 1)} = \frac{p_{ij}}{p_{i1}} = \exp(\beta_{1j} + \beta_{2j} x_i), \quad j = 2, 3 \quad (\text{eq8})$$

The effect on the probability ratio of changing the value of x_i is given by the derivative

$$\frac{\partial(p_{ij}/p_{i1})}{\partial x_i} = \beta_{2j} \exp(\beta_{1j} + \beta_{2j} x_i), \quad j = 2, 3 \quad (\text{eq9})$$

The value of the exponential function $\exp(\beta_{1j} + \beta_{2j} x_i)$ is always positive. Thus, the sign of β_{2j} tells whether a change in x_i will make the j th category more or less likely relative to the first category.

An interesting feature of the probability ratio is that it does not depend on how many alternatives there are in total. There is the implicit assumption in logit models that the probability ratio between any pair of alternatives is independent of irrelevant alternatives (IIA).

Relative risk ratios describe the multiplicative effect of a unit increase in each predictor as the odds of observing a particular category (Hamilton, 2013). Here in this case, ‘structurally developing’ or ‘structurally developed’ responses instead of the base category ‘structurally underdeveloped’.

5. Results and Discussions

This section presents the results of the study. They are organised into descriptive statistics, graphical illustrations of our relationships, and econometric baseline and robustness results.

5.1. Descriptive statistics

5.1.1. Summary details of variables

Table 12 below displays the various summary statistics for the full sample, for the studied period. The percentage of agricultural land in the full sample is 45, 88%, but with great disparities in the sample, as the standard deviation is 20.4. To add up, the lowest value of agricultural land is 3.26% of the land area while the highest is up to 82.67% of the land area. Increasing land area by using agricultural land brings changes to countries and may generate industrial development.

Table 12: Descriptive statistics of the overall sample

	aland	arlandcap	gdpcap	popg	gov	pland	trade
Mean	45.879	0.258	2054.287	0.0253	5.377	2.951	67.221
S.d.	20.391	0.184	3037.133	0.0114	1.792	5.145	35.098
Min	3.260	0.0015	164.337	-0.0677	1.063	.00176	19.68
Max	82.671	1.516	20532.95	0.0812	10	29.554	311.35
Obs	1101	1104	1090	1061	738	1101	1018

Source : author

More than 4 out of 5 people practice agriculture. On average, arable land per capita is 0.26 Ha. The variable has homogeneous behaviour, as the overall standard deviation is low (0.18). The lowest value of arable land per person is 0.0015 Ha, while the highest value is 1.52 Ha. This is in line with the literature which holds that most Sub-Saharan Africa farmers are smallholders, with farm size lower than 2 Ha (Masere and Worth, 2022; Ncoyini et al., 2022).

Over the study period, average of per capita GDP \$2054.29. However, the standard deviation of 3037, implies great disparities in this variable distribution around the mean. This can explain why the minimum value of GDP is \$164.34 while the maximum GDP value culminates at \$20,532.95.

The arithmetic mean of the variable population growth is 2.5%, which shows that the population growth rate over the period is relatively low. With the low standard deviation of the variable, 0.011, it is assumed that there is not too much heterogeneity for demographic change distribution. Some countries have a negative rate of population growth due to wars⁶. The highest rate of demographic increase is 0.812 recorded in Rwanda, between 1998–99.

⁶ Example, the civil war and Tutsi genocide in Rwanda between 1991 and 1994.

The institutional or governance index indicates an overall average of 5.38. This means that countries display neither too bad nor too good governance. Which should be interpreted with cautions, as the standard deviation its 1.79. The smallest value of our indicator is 1,063 for countries with low institutional quality (Democratic Republic of Congo), and the highest value is 10 for well-established democracy countries (such as Mauritius and Botswana).

Permanent crop land average is 2.95%, with wide disparities in its distribution. The minimum portion of permanent cropland is 0.002 recorded by Botswana. On the other hand, the highest value of permanent cropland is 29.55% recorded in Comoros in 2004.

The variable trade displays an average of 67.22% but the variable dispersion is average. Indeed, the standard deviation of the variable is approximately 35. The lowest contribution of Trade in a country's GDP is 20% while the highest is close to 311%.

5.1.2. Analysing the within and between variation of types of structural change

Table 13 provides more details about both within and between variations of the dependent variable (type of structural change) of the sample of 41 countries. The overall summary shows that 73% of the 807 country-year observations had structurally underdevelopment, almost 20% had structurally developing and only 7% had structurally developed.

Table 13: Summary statistics of the dependant variable.

<i>TSC</i>	Overall		Between		Within
	Freq.	Percent	Freq.	Percent	Percent
Structurally Underdeveloped	807	72.90	36	87.80	83.02
Structurally Developing	219	19.78	41	100.00	19.78
Structurally Developed	81	7.32	6	14.63	50.00
Total	1107	100.00	83	202.44	50.00
	(n = 41)				

Source: author.

The between summary informs that, of the 41 countries, 87.80% had structurally underdeveloped status at least once, every country had at least once a structural developing status and only 14.63% countries had structurally developed status at least. The between total percentage is 202.44% because all the countries (102.44%) had some of the time, the structural underdevelopment status and some of the time another status between structurally developing or developed and are therefore counted twice.

Looking at within summary, it indicates that 83% of countries structurally underdeveloped never escaped to this status during the period of study (1990–2016). Conversely, 20% of the countries that were at the structurally developing stage have not changed their status. In a similar way, 50% of the countries remained in their category of structurally developed. This means structurally underdeveloped stage is the most stable status, followed by the structurally developed stage. Further, a description of the states of structural change helps to analyse probabilities for a country to move from one step to the other.

5.2. Agricultural land expansion and labour movements

Here is documented the graphical relationship between agricultural expansion and movements of labour. This gives an overview of agricultural land expansion, then links agricultural expansion with labour spillovers.

5.2.1. Agricultural land expansion evolution

The agricultural land trend is plotted in the general introduction to this thesis (figure 2). It shows agricultural land-use coupled to an expansion movement of the agricultural sector. This means an expansion of agriculture similar to Barbier (2021). However, this agricultural land expansion may generate two opposite outcomes in terms labour movements.

5.2.2. Sectors value added response to agricultural land expansion

Structural change process is the reallocation of production factors from low productivity sectors to high productivity sectors (Bloem, 2019). More generally, the process describes movements production factors among sectors, irrespective of their productivity. It is also known that structural change entails that the contribution of agricultural value added in the overall value-added decreases, while the service's sector increases continuously and that of the industrial sector has an inverted – U shape (Herrendorf et al., 2014).

As a result of the expansion of agricultural land, the value-added shares of different sectors were analysed (Figure 12). The graphs give within variations, to explain GDP shares of sectors are associated with agricultural land expansion in countries. To identify possible optimums for value-added shares as agricultural land increases requires a quadratic adjustment for each sector. It appears that each sector has special behaviours illustrated by the three sub-figures.

Firstly, figure 12a shows an inverse relationship between agricultural land expansion and agricultural value-added share. High shares of agricultural sector value added to the total value added are associated with low areas of agricultural land. In contrast low levels of agricultural value added shares are associated with high agricultural land. This feature is in line with the theory of structural change,

which states that agriculture should back the growth of other sectors. Therefore, its own contribution to the overall value added should decrease. Then, the adjustment line is downward sloping, so the proportion of agricultural sector value added reduces as agricultural land expands. However, this feature of structural change is not followed by expected movements of shares of other sectors.



Figure 12: Sectoral value-added share and agricultural land
Source: author.

Looking at figure 12b, a ‘U relationship’ between the secondary sector value added share and agricultural land is visible. This illustrates the importance of agriculture land for industrial GDP. Agricultural land expansion first of all, makes the share of the industrial sector to decrease, and then, to rise. Assuming that the percentage of agricultural land is the input and industrial value added is the output, then increasing returns and decreasing returns are observed. An increase in the former causes an increase in industrial value-added share before 46% of agricultural land area. However, diminishing returns operate when agricultural land exceeds 46%. From that level, any increase in agricultural land causes the proportion of the industrial value added to increase and to contribute more to overall value added. This means that diminishing returns of the land factor are overcome by increasing returns when agricultural land reaches and exceeds 46% of the country’s total land area. Thus, expanding agricultural land may be a good way to promote structural change.

Finally, figure 12c displays the inverted–U relationship between agricultural land and services value-added share. The tertiary service value added contributes the greatest percentage to overall value added. The higher the percentage of agricultural land the faster the tertiarisation process goes on but slows down when the percentage of expansion approaches 46%. This is where the law of

decreasing returns operates. After 46%, any marginal increase in agricultural land generates constant and further, increasing returns. The latter is characterized by the decrease in the value added of the service sector. Thus, increasing agricultural land to that extent will generate a less important contribution of the service sector to the overall value added of countries.

To sum up, the study shows that agricultural land increase is associated with different contributions of sectoral value added to the overall value added. Following the extensification of agriculture, the agricultural sector's contribution to total value-added decreases steadily at a high rate. However, converting land area for agriculture use, will likely reduce the value added of industrial output and then, cause industrial output to increase faster than the increase of overall output. Finally, as agricultural land increases, countries start by enjoying raising contribution of service sector value added in the overall GDP, followed by a fall, at the benefit of industrialisation. These stylised facts emphasise the suspected relationship that agricultural expansion generates an industrial type of structural change

5.2.3. Agricultural land expansion and labour spillovers: Overall

The labour spillovers refer to movements from the agricultural sector to either the industry or to the services sector. To show the link between agricultural land expansion and the different outward movements of labour, one proceeded in two steps: (1) linking agricultural land expansion and spillovers for an overall variation, and (2) linking the same variables for a within variation.

5.2.3.1. Linking agricultural land and labour spillovers: Overall

The above figure 13 relates labour movements into different sectors with agricultural land growth, for all countries and on overall period of time. Despite the fact that the countries are stuck in the agricultural sector, there is a direct relationship between agricultural expansion and an increase in industrial share (figure 13a) or service share (figure 13b).

The slope of the linear adjustment between land and movements industry seems to be flatter than that of land and labour spillovers into service. Authors find that the increase in industrial value added is a response of land-use expansion (Mensah et al., 2016). These figures illustrate that agriculture also leads to a service – oriented structural change. However, with respect to its sharper slope, expanding land seems to have a greater impact on inward industrial labour movements.

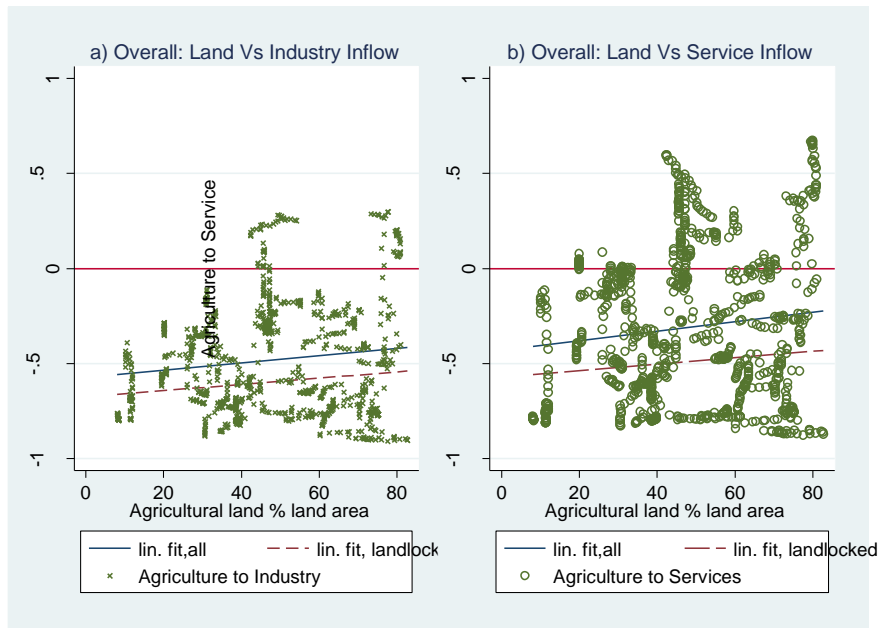


Figure 13: Agricultural land vs industry and services spillovers, overall
Source: author.

In addition, it appears that landlocked countries have lower and flatter adjustment lines. The lower adjustment fitting reveals that landlocked countries have smaller average spillovers than other countries, in general. On the other hand, the flatter adjustment lines show the smaller responsiveness of labour movements to land expansion for these countries.

5.2.3.2. Linking agricultural land and labour spillovers: within variation

The figure 13 illustrates the link of how movements of workers from agriculture to industry (figure 14a) or to service (figure 14b) are related with growth of agricultural land. This means, for the same country it shows how labour movements react to land expansion over time. One notices a direct relationship between the variables. As agricultural land increases more people are moving to the industrial sector, and the service sector alike.

As the country increases its cultivated area across time, the labour force is attracted in both the industrial and service sectors. A vast majority of spillovers is still negative, showing that sub-Saharan Africa countries remains concentrated in the agricultural sector. Only few countries have positive industrial spillovers (about 2 points), while several tertiary spillovers are above the zero line.



Figure 14: Agricultural land vs industrial and services spillovers, within variation
Source: author.

The adjustment line of the service sector is above that of the industrial sector, showing the higher employment share of the service sector, and a shrinking industrial sector. Moreover, the slopes of the lines are almost identical, with that of the service sector slightly steeper than that of the industrial sector. Hence, as agriculture land expands across time, workers' movement into industry is almost equal to workers' movement into the service sector.

5.2.3.3. Linking agricultural land and labour spillovers between variation.

Finally, the researcher analyses the variation across individuals known as between variation, where the main assumption is the homogeneity of the unit or the country. The graphs of figure 15 show similar characteristics and relationships as the previous models. More precisely, the countries are still agrarian, with a steady progress toward industrialisation (figure 15a) and a slightly fast work toward the service sector. Nonetheless, the slopes of the adjustment lines are almost the same. Thus, continuous expansion of land within its availability will result in almost equal responsiveness of both secondary and tertiary sector.

When compared with all countries, landlocked countries' adjustment lines are still below all countries. This indicates that they are more agrarian than other sub-Saharan countries. An important feature is that the curves are of flatter slopes, which means that structural change is slower than in other countries when agriculture expands

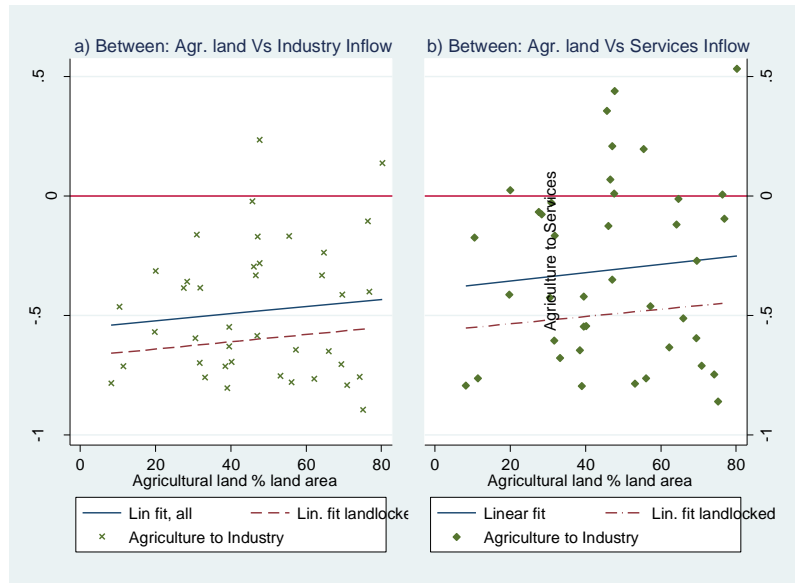


Figure 15: Agricultural land vs industrial and services spillovers, between
Source: author.

5.3. Estimation results

This subsection is subdivided into two: the stationarity tests results and the estimation results

5.3.1. Stationarity tests

Here the stationarity results of variables of the models illustrated in table 14 are presented. The Im-Peasaran-Shin (2003) unit root test which is a second-generation test, shows that all the variables are stationary at level. So, there is no need to differentiate them.

Table 14: Unit root test

Variables	ips	
	Decision	P-values
Agricultural land	I(0)	0,03
Agricultural land per capita	I(0)	0,02
GDP per capita (log)	I(0)	0,0001
Population growth	I(0)	0,084
Governance Index	I(0)	0.0775
Trade	I(0)	0,001
Permanent crop land	I(0)	0,084
Mineral rent	I(0)	0,084

Source: author.

It is not possible to perform a stationarity test for categorical variables, there is no unit root test nor stationarity test allowing to identify the level of integration of a categorical variable. Additionally, being stationary at level is disqualifying for estimator time.

5.3.2. Baseline model results

5.3.2.1. Estimation Results

At first glance, the number of observations varies between 1,034 and 690, for 41 countries included in the sample. Multinomial regressions (POMLOGIT) show acceptable statistical characteristics. The pseudo-R² statistic varies between 0.41 and 0.58. The LR Chi² coefficients of overall significance of all regression coefficients are high and statistically significant at the 1% level.

From table 15 a major fact emerges. The variable of interest *agricultural land* is statistically significant in all regressions (1–3). Thus, it withstands different model specifications. In addition, it is noted that the variable land expansion, always and for all models, displays a higher coefficient in the equation of the structurally developed category.

Model POMLOGIT2 indicates that an agricultural land expansion of one percentage point significantly increases the likelihood of a country being structurally developing, rather than structurally underdeveloped, by 8.8%. Similarly, increasing the same agricultural expansion variable by one percentage point increases by 32% the likelihood of a country being structurally developed rather than structurally underdeveloped.

The variable is significant at 1% level. This reflects that agricultural expansion has increased potential to transform structurally underdeveloped economies into structurally developed countries, all other things being equal. Several studies lead to a similar result (Barbier, 2020; 2021) which establishes that agricultural expansion is a source of economic growth according to a Solow-Swan model formulated by Solow (1956). On the other hand, this study diverges from Mensah et al. (2016) establishing that the increase in arable land results in a greater increase in tertiary value added.

The variable per capita arable land is not significant for any category. An increase in land per person by 1 ha reduces by 32% the probability of being a structurally developing country to the benefit of being structurally underdeveloped. Conversely, the same increase of 1 ha per inhabitant raises the probability of being structurally developed instead of being structurally underdeveloped. This means that increasing land ownership, attracts people in the agricultural sector. However, this is insufficient enough to build up an industrial-oriented structural change. This outcome is in line with country specific analyses (Rozaki, 2020; Yeboah et al., 2019) and diverges from Mensah et al. (2016). Possibly, poor poverty constraints force smallholders to practice subsistence farming with low transformation potential. Additionally, the lack of access to capital, infrastructure, and technology further impede the development of the agricultural sector. This means that even if the land is in people's hands, they may not be able to make use of it effectively. Without access to capital and

technology, smallholders are unable to make the investments they need to move beyond subsistence farming and into a more profitable and sustainable agricultural sector.

Table 15: Results of the baseline model

Variables	POMLOGIT 1		POMLOGIT 2		POMLOGIT 3	
	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed
Agricultural land	1.050** (0.0232)	1.180** (0.0907)	1.088*** (0.0292)	1.319*** (0.0741)	0.948 (0.106)	0.496*** (0.0970)
Ag. land (t-1)					1.148 (0.133)	2.702*** (0.609)
Ag. land per cap	3.314 (11.45)	0.968 (4.774)	0.320 (1.589)	15.09 (37.45)	0.361 (1.784)	32.22 (73.37)
aglXva	0.999 (0.000545)	0.994** (0.00242)	0.999 (0.000796)	0.988*** (0.00300)	0.999 (0.000793)	0.987*** (0.00371)
GDP p cap (log)	3.160** (1.459)	0.120 (0.174)	9.120*** (4.676)	0.0373*** (0.0342)	9.171*** (4.697)	0.0273*** (0.0284)
Pop. growth	3.73e-08 (1.39e-06)	0.0001** (0.004)	0.0001* (0.006)	0.0001*** (1.45e-06)	0.0001* (0.0015)	0.00001*** (0.004)
Governance	1.698*** (0.342)	8.633* (10.28)	1.761*** (0.351)	19.07*** (12.90)	1.767*** (0.356)	21.64*** (15.57)
Landlocked (1 if yes)	0.226* (0.184)	0.0968 (0.275)	0.312 (0.262)	0.203 (0.340)	0.305 (0.251)	0.217 (0.320)
Trade	1.008 (0.0116)	0.996 (0.0315)	1.005 (0.0109)	1.003 (0.0150)	1.005 (0.0109)	1.005 (0.0138)
popgXagva			9.808** (10.77)	200,245*** (421,223)	9.770** (10.73)	346,337*** (811,825)
Perm. cropland			0.772** (0.0820)	0.989 (0.294)	0.771** (0.0825)	1.022 (0.357)
Mineral rent			0.986 (0.0604)	1.155 (0.444)	0.986 (0.0610)	1.163 (0.460)
Constant	6.48e-07*** (3.44e-06)	0.315 (2.638)	2.54e-10*** (1.55e-09)	1.144 (9.953)	2.33e-10*** (1.43e-09)	1.587 (12.64)
Observations	690	690	690	690	690	690
Pseudo R2	0.530	0.530	0.578	0.578	0.581	0.581
N	41	41	41	41	41	41
chi2	557.2***	557.2***	1523***	1523***	2386***	2386***
Wald Test		25.58***		17.93***		12,99***
Chi2(2)						
Ag. land						
Ag. land (t-1)						19,49***

Robust se eform in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: author.

The first reason is that low education levels hinder people's ability to make effective use of the land they have (Martins, 2019). The second reason relates to the drudgery imposed by agricultural activities and the insufficient modernisation of agriculture. This may suggest that land may remain unused. Owning more land will be welcomed by people, but it might not be used for agricultural production. As a result, industrial output is likely to remain low. A proper land policy should accompany those with agriculture experiences, skills and knowledge in the process of acquiring agricultural lands.

No matter what model specification is used, GDP per capita always has a significant effect on structural change. The magnitude, however, depends on the model specification. According to the

preferred model (POMLOGIT 2), an increase of \$1 in per capita GDP increases 10 times the likelihood that the country becomes structurally developing rather than structurally underdeveloped. Contrarily, the same rise in GDP per head will reduce by 35% the relative probability for a country of being structurally underdeveloped. This means the actual growth of African countries is mostly beneficial to the service sector, and less to the industrial sector. This result contradicts Mensah et al. (2016) who found that the elasticity of manufacturing value added with respect to the log of income per capita is significantly higher than in the service sector. It can be argued that countries lack incentives to promote industrial sector expansion, scaring away both domestic and foreign investors. One is more likely to encounter many people in the agricultural sector than in the secondary sector. Conversely, the improvement of population living standards can lead them into the service sector. This is less risky and has similar characteristics to the agricultural sector.

Taking into account the population growth, estimated coefficients are always significant in the regressions, but less than one in the preferred model (model 2). The relative risk ratios are close to zero, but highly significant. When population grows the relative risk of being either structurally developing or structurally developed reduces to the merit of being structurally underdeveloped. Population growth increases the probability of a country becoming more agrarian. One justification of such a fact, is that directly or indirectly, 80% of the population in Africa practises agriculture, so a positive demographic shock, increases at a very low rate, but with a high significance, the probability of the workforce being located in the agricultural sector. The result is in line with the finding of Barbier (2020) which shows that when the demographic rate climbs, it contracts the growth expansion. It is distinct from Totouom et al. (2019) asserting that population growth increases the manufactured value added.

The institutional quality variable (*Gov*), is significant at the 10% threshold in all specifications. The variable coefficient is always greater in structurally developed equations. According to the preferred model (model 3), an improvement in institutional quality increases the relative risk by 76%, resulting in a structurally developing country rather than an underdeveloped one. This result differs from Mensah et al. (2016) whose work finds that the democracy index reduces the service sector share in overall GDP.

Nonetheless, improving the quality of governance (*Gov*) multiplies by almost 19 the ratio risk of being structurally developed industrial instead of being structurally underdeveloped. Arguments supporting this result include the promotion of a good business climate. Effective governance allows governments to formulate and execute the industrial policies required for their economies to structurally transform; they discourage unproductive rent-seeking and harmful business practices.

Also, it improves the business climate which in turn attracts investors. Another explanation may be government policy to promote modernization (using modern inputs), or by intervening on the land rental market, or by promoting land registration. It further may increase their will to invest in the transformation of their own products, thereby resulting in structural change. This result is close to both theoretical developments (Edokat and Njong, 2019) and to empirical findings (Totouom et al., 2019; Martins 2019). The former holds that good institutional quality hinders structural change and economic growth in sub-Saharan Africa. The latter reveals that institutions are key determinants of industrial performance growth in Sub-Saharan Africa.

In this essay, we discuss whether a country's landlocked status affects the type of structural change it experiences. The landlocked dummy variable ($1 = \text{if landlocked}$) is introduced in the regressions. The estimations suggest that statistically, it has no significant effect on the type of structural change. Despite this fact, models 2–4 show that the coefficients for the structurally developing equations are greater than those of the structurally developed. The chances of a landlocked country reaching the structurally developing stage instead of underdeveloped stage are 69% lower than those of an opened sea country, all other factors remaining the same. Similarly, landlocked country has 80% fewer chances of attaining the structurally developed stage rather than being at the underdeveloped stage. Although this sounds like a ‘curse’, it can be explained by the high cost of transportation, which inhibits the development and participation in Global Value Chains. This in turn holds the labour force in the agricultural sector and makes them more ready to transit in the service sector. The results are consistent with those in the literature (Collier, 2007; Sachs 2007). The statistical non-significant result indicates that discrimination against landlocked countries can be overcome, and that the ‘curse’ can be broken.

International openness measured by *trade* variable has no explanatory power in our models. Despite the fact that trade coefficients are not significant in model 3, one identifies a direct relationship between trade and the probability of countries having a greater labour force in the tertiary sector than in the agricultural sector. When the ratio of trade increases by one percentage point, the countries have 0.5% more chances of being of the structurally developing type than structurally underdeveloped. Similarly, every 1 percentage point increase in international trade value added increases by 0.3% the likelihood of an 'industrial-oriented' type structural change than no structural change.. Hence, trade is more likely to lead economies to a ‘service-type’ of structural change. Plausible justification for this outcome is found in the constitution of the tertiary sector in Africa. Tertiary services are mostly informal activities and retail sales, while the secondary sector comprises more efficient firms. In order to capture the benefits of trade improvements, people will be motivated

to invest in services sectors with fewer barriers. It is also convincing that firms' trade growth favors people's willingness to invest in the industrial sector. This result is different from a similar study in the literature (Thurlow and Wobst, 2005), which shows that trade liberalisation in Zambia had the unintended consequence that low-skilled workers were shed from manufacturing industries and ended up back in agriculture.

The expansion of land under permanent crops reduces by 23% the relative risk of observing service type of structural change than underdeveloped type of structural change. This is significant at the threshold of 1% in models 2 and 3. Here, expanding permanent cropland under cultivation is more likely to make a country more agrarian. This is justified because perennial crops need more care during their lifespan. Agricultural farms will then hire workers to maintain crops, reducing services sector employment. Contrarily, an increase in perennial cropland has had little impact on industrial development. In model 3, it lowers by 2.1% the relative risk of observing industrial-type of structural change than the agrarian-type of structural change. In model 4, it increases by 2.2% the probability of having structurally developed than structurally underdeveloped countries.

The natural endowments proxied by the *mineral rent* variable has the expected relation with the industrial-type of structural change. Indeed, an increase by one percentage point of the rent value added increases by 15% the probability of a country to be of the structurally developed category than the underdeveloped category. Meanwhile, where rent increases by 1 percentage point, it reduces by about 2%. This reduces relative probability of observing a 'service – type' of structural change than structural underdevelopment. Despite not being statistically significant, the result approximates that of Mensah et al. (2016). It traduces a better management of rents from natural endowments. In the similar vein, management of the resources by Africans will retain direct capital flight from Africa and stimulate better sustainable development (Njimted and Yakum, 2019).

The interaction variable of agricultural land expansion and agricultural real value added (*AgIXval*) is significant at the 1% threshold in equation of structurally develop. An increase of agricultural land and real value added will reduce by 1.4–2.3% the relative probability of having structural developed countries than structural underdeveloped countries. This can translate the fact that the raw materials are sold without transformation. It could encourage some industries to engage backward vertical integration. Indeed, Africa low mechanisation levels will increase the proportion of workers to support the productivity of the agricultural sector, other things held constant. On the other hand, increase of variables (*AgIXva*) will allow unchanged the relative risk of observing tertiary type of structural change than the absence of structural change. The result deviates from the findings of Barbier (2020).

Interaction variable of population and agricultural value added in real terms (*popgXagva*) appears to have significant contributions in the models. A simultaneous population and agricultural growth will multiply by 9.7–9.8 times the relative risk of observing a ‘service-type’ of structural change than the underdeveloped type of structural transformation. The result is significant at the level of 5%. Simultaneous population and agricultural growth have high impact on the probability observing a structurally developed country than a structurally underdeveloped country. Demographic pressure and agricultural expansion increase at the threshold of 1% the relative risk that a country follows more paths of industrial structural change than remaining in the agrarian stage of structural transformation. This result is close to that of Barbier (2020).

While controlling last year’s land expansion for agriculture (*L. aland*), findings suggest similarities with model 2. In spite of the insignificance of agricultural expansion on the structurally developing equation, two important results from the structurally developed equation are derived. The agricultural land expansion in the current year and the year before is statistically significant at the threshold of 1%. It is found that a 1% expansion of land during the current year decreases by 51% the probability of observing structural development than structural underdevelopment. It shows that the expansion of land will increase the probability that people will move from the industrial sector to the agricultural sector, *ceteris paribus*. The contemporaneous effect of land expansion changes the economy to an agrarian one. However, the effect is cleansed by last year’s land growth. The last year’s 1% increase in land multiplies by 1.7 the probability for countries to engage in industrial-type of structural transformation instead of being agrarian. This indicates that last year’s expansion will provide a greater opportunity for industrial oriented structural change. This result is robust and corresponds to literature findings that suggest agriculture generates local economic spillovers (Fuglie and Rada, 2013). It rather differs from (Hornbeck and Keskin, 2011) who find that agricultural gains generate short-run benefits but not long-term benefits for the non-agricultural sector.

5.3.2.2. Margins effects of agricultural land on structural change

Here, the margin effects of agricultural land on the probabilities are analysed to observe each outcome of the structural change variable in Africa. Results are differentiated between opened sea and landlocked countries. Then the combined effects of agricultural land and governance on the probability to observe specific structural change is interpreted.

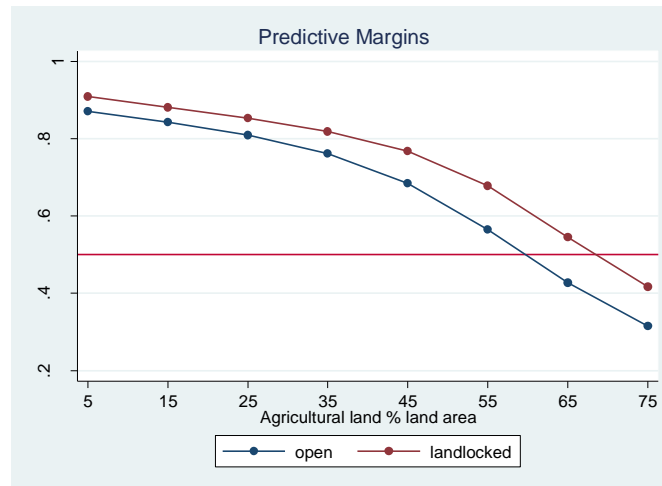


Figure 16: Marginal effects of agricultural land expansion on probability of structurally underdeveloped economy
Source: author.

a. Marginal effects of agricultural land expansion on the probability of being a structurally underdeveloped economy

To start up, figure 16 highlights the relationship between the probability of observing an underdeveloped type of structural change and agricultural expansion for countries with a sea coast and landlocked ones. In both categories of countries, two similar phenomena operate at the same time.

The first phenomenon is concerned with the nature of the relationship between the two variables. It shows that there is an inverse and significant relationship between the expansion of agricultural land and the probability of observing an economic structure of the underdeveloped type. The more land increases, the more agricultural sectors release labour for other sectors.

The second phenomenon is concerned with the sensitivity of this relationship. It is noted that the relationship is less sensitive to the increase in agricultural land when it represents less than 45% of the total surface of the country. Promoting the expansion of agricultural land does not always decrease the likelihood of having an agrarian economy. However, above 45%, this probability decreases more noticeably with agricultural land expansion. This result is in line with that of Johnson and Vollrath (2020) which shows that the higher the land elasticity of agricultural production, the greater the propensity of individuals to leave the agricultural sector.

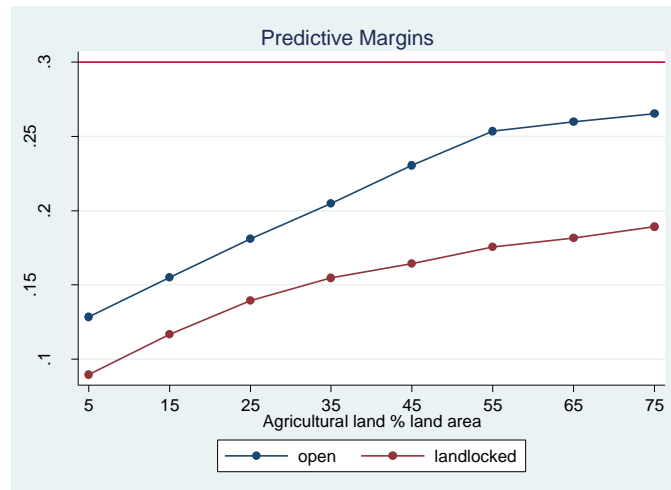


Figure 17: Marginal effects of agricultural land expansion on probability of structurally developing economy
Source: author.

There are similarities and differences between depending on the openness of the countries to the sea. Like countries with an opening to the sea, landlocked countries have an inverse relationship between the probability of observing an agrarian economy and agricultural expansion. In addition, this probability decreases timidly before the average of 45% and then accelerates after the average. The difference between landlocked countries and countries open to the sea is that landlocked countries are always more agrarian than countries with a sea coast. Landlocked countries, need an agricultural land expansion of 65% to to move from structural underdevelopment. However, an agricultural land expansion of 60%, is associated with the probability to observe an agrarian economy as a non-agrarian economy in sea-opening. This gap is not closing.

b. Marginal effects of agricultural land expansion on the probability of being a structurally developing economy

Then, figure 17 above highlights the relationship between the probability of observing a tertiary-type structural change and agricultural land increase. The two variables appear to be positively correlated at first glance. Between 5% and 45%, one notes that the increase in land is accompanied by a monotonous increase in the probability of observing a tertiary economy, both for countries open to the sea and for landlocked countries. For the latter, however, the effect is slower. This results is close to Cadot et al. (2016).

The second major fact emerging is that 45% and 75% of the ‘tertiarisation process’ seem to be running out of steam. An agricultural land expansion is accompanied by an increase in the probability of observing a developing economic structure, to a lesser extent. Lastly, the third fact observed is that countries open to the sea are more likely to develop a service sector than those without an opening to the sea. They have a lower observation curve and weaker growth than countries with costal openings.

This can be explained by the lower transport costs for non-landlocked countries, as well as the abundance of imported products, which facilitate integration into and being member in the tertiary sector which is mainly made up of informal activities, trade in retail and distribution. This result is in line with Mensah et al. (2016);

c. Marginal effects of agricultural land expansion on the probability of being a structurally developed economy

Finally, figure 18 establishes the relationship between the probability of observing an economic structure of the developed or industrialised type and the expansion of agricultural land. Two major facts emerge from this modelling.

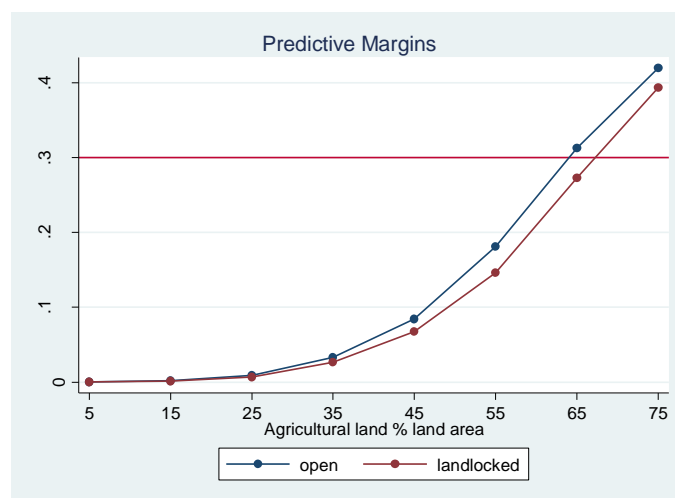


Figure 18: Marginal effects of agricultural land expansion on probability of structurally developed economy
Source: author.

The direct relationship between the probability of observing an industrialised economy and agricultural expansion as well as the difference in the process of structural transformation depends on whether the countries have an opening to the sea. The first fact is in line with the research hypothesis of this essay. Indeed, agricultural expansion is a significant determinant for industrial structural transformation in sub-Saharan Africa. It is observed that the expansion of land-use is accompanied by an increase in the probability of observing an economy with an industrial structure. This process has two sub-phases, as identified in the previous types of structural change.

The first is set for expansion between 5% and 45%. It is characterised by a low sensitivity to the country's probability of having an industrial structure as expansion continues. The second sub-phase is established at 45%. The model predicts a probability of observing an industrial structure that grows at increasing rate, following the expansion of agricultural land. The second fact emerges from the comparison between sea-opened countries and landlocked. Unlike the other predicted probabilities, the probability of observing a developed economic structure is initially zero for the two categories of

countries. Therefore, the countries open to the sea have an advantage, and develop a more industrialised economic structure than landlocked countries. This shows that agricultural expansion generates a faster structural industrialisation process for countries adjacent to the sea than for other countries, all other things being equal.

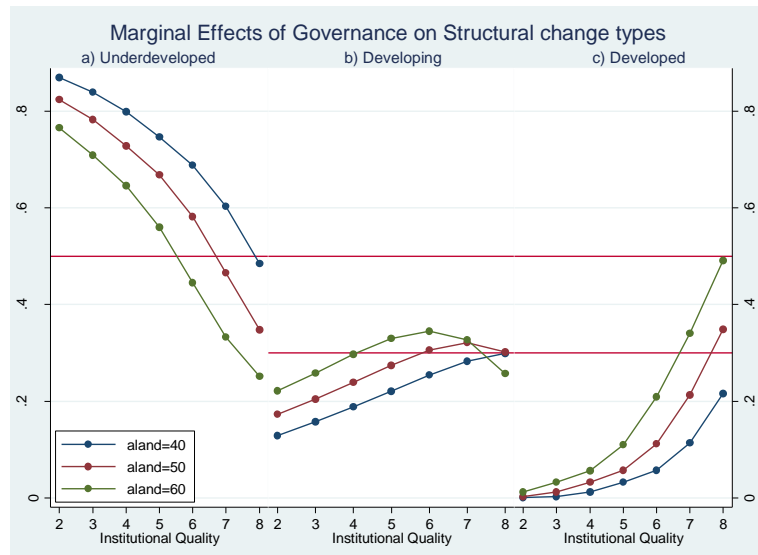


Figure 19: Marginal effects of Governance on types of structural change
Source: author.

d. Analysing the Marginal effects of Governance on types of Structural Change

Figure 19, helps to examine the marginal effects of institutional quality on types of structural change. One starts with the structurally underdeveloped type, then followed by the developing, and ended with the structurally developed type.

First, when it comes to agrarian economies (figure 19a) there is an inverse relationship between improving the quality of institutions and the probability of observing a structurally underdeveloped economy. In addition, the relationship is strengthening as agricultural expansion continues. Thus, countries with 40% agricultural land have a lower probability of releasing labour in other sectors, than countries with 60% land expansion. In addition, the likelihood of observing a structurally underdeveloped economy decreases rapidly as institution quality improves. Thus, it is important to combine land-use expansion with improving quality of institutions. Indeed, better land governance integrated into agricultural policies, a land market allocating land efficiently to farmers, would encourage the exodus of labour to other sectors. This result is similar to that of Johnson and Vollrath (2020) which shows that in the event of a positive productivity shock, for regions with high elasticity – land – as shown in the previous subsection – s’ accompanied by a release of the agricultural workforce towards other sectors.

Secondly, Figure 19b explores for each level of agricultural expansion, the marginal effect of improving quality of institutions on the probability of observing a tertiary economy. The figure discloses an inverted-U relationship, for different levels of expansion. Improved governance promotes the tertiarisation. However, it has a threshold which depends on agricultural expansions. This result is different from that of Mensah et al. (2016) who show in particular that a qualitative leap in governance would have a negative and insignificant effect on the value added of the tertiary sector.

Table 16 : Effects of agricultural land expansion on stages of structural change: Random effects

Variables	REMLOGIT (1)		REMLOGIT (2)		REMLOGIT (3)	
	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed
Agricultural land	1.101*** (0.0205)	1.730*** (0.300)	1.232*** (0.0444)	1.753*** (0.260)	1.154*** (0.0346)	2.829*** (1.109)
Perm cropland	0.846* (0.0768)	1.164 (1.281)	0.910 (0.0979)	0.405 (0.417)	0.898 (0.0818)	0.209 (0.353)
Ag land per cap	0.137 (0.360)	7.107e+09** (7.630e+10)	0.0184 (0.0548)	16,54 (1,473)	0.000703** (0.00206)	0.709 (8.317)
AglXva	0.998*** (0.000720)	0.976*** (0.00911)	0.997*** (0.000934)	0.983** (0.00771)	0.998*** (0.000807)	0.970** (0.0136)
Lngdpcap	6.786*** (2.740)	402.2** (1,002)	14.40*** (7.618)	0.0453 (0.175)	6.588*** (3.128)	0.00415 (0.0241)
Pop. growth	0*** (0)	2.255e+44 (2.199e+46)	0 (0)	4.410e+42 (6.763e+44)	0** (0)	3.978e+103 (9.961e+105)
Governance	1.692*** (0.311)	65.55*** (88.78)	7.119*** (2.313)	35.44*** (526.1)	3.590*** (0.866)	18.96*** (4,948)
Landlocked (1 if yes)	0.0596*** (0.0559)	7,022** (24,841)	0.212 (0.234)	109.9* (286.5)	0.253 (0.285)	0.354 (1.408)
Trade			1.026*** (0.00854)	1.156*** (0.0639)	1.032*** (0.00845)	1.279** (0.139)
Mineral rent					1.030 (0.0414)	0.777 (0.197)
Constant	1.25e-08*** (4.63e-08)	0*** (0)	0*** (0)	0* (0)	5.92e-11*** (3.07e-10)	0 (0)
RI2[c_id]		1		1		1
RI3[c_id]		1		1		1
var(RI2[c_id])		265.6*** (371.4)		89,116*** (287,249)		794.9*** (1,418)
var(RI3[c_id])		5.884e+31* (2.612e+33)		5.300e+07** (4.724e+08)		4.770e+75 (6.149e+77)
cov(RI3[c_id] ,RI2[c_id])		1.709 (3.821)		0.189 (0.565)		0.972 (2.241)
N	712	712	690	690	690	690
k	24	24	26	26	28	28

se Eform in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: author.

The present result is justified because, with poor quality institutions such as corruption, lack of regulation, political instability, workers are generally forced to invest in temporary and informal activities to protect themselves from the prevailing corrosive institutional climate, so as to make the most of it. When democratic institutions take hold, informal activities ceases and the curve decreases.

In addition, it is noted that the combined effect of improving the quality of institutions and agricultural expansion slows down faster the vicious explosion of the tertiary sector, to the benefit of the secondary sector, than does agricultural expansion alone.

Finally, figure 19c describes the marginal relationship between the probability of observing an industrialised-type of structural transformation and the qualitative strengthening of institutions. One of the most important findings is that the quality of institutions has a positive relationship with industrialisation. Greater political stability and democracy are conducive to the transformation of the economic structure to accommodate more industries. The probability of observing industrial-type structural change increases rapidly. This result is similar to those who show the theoretical link between governance and structural change (Edokat and Njong, 2019), and those who test it empirically (Totouom et al., 2019). In addition to this result, it is noted that for countries with high agricultural land expansion, the effect of improving quality of institutions is greater. Hence, governance is an essential component in generating virtuous structural change, which promotes industrialisation.

5.3.3. Robustness Check

The results obtained from the estimation of equation (1) in table 16 show that agricultural land enhances the industrial type of structural change in the region. Hence, the validity of our results is verified by robustness checks. Firstly, alternative specifications were considered to confirm the baseline results displayed in table 11. Moreover, an alternative estimation technique was used, namely the Multinomial Logit with Random effects.

5.3.3.1. Alternative model estimation

a. Random effects

Looking at models in columns 1 to 3, it is observed that the significance of the expansion variable is the same. Agricultural expansion promotes industrial type of structural change. In each column, the probability of experiencing an industrial-oriented structural change is greater than having an underdeveloped structure. This risk, in favour of an industrial structure, is greater than the probability of observing a tertiary economic structure compared to an agrarian economy. Agricultural expansion increases the probability tertiarisation of the economy. However, it is more likely to contribute to cause the industrialisation of the economic structure (columns 1–3).

The variable of land under permanent crop land does not withstand the specifications of the model. In columns 3–4 the variable is not significant and it reduces the probability of observing structurally developed countries relative to underdeveloped countries. There is a similar relationship between

being structurally developing and structurally underdeveloped. In the second model, on the other hand, the variable has no significant effect on the probability of observing an industrial type of transformation rather than an underdeveloped economic structure. However, the variable reduces by 15% the risk of observing a tertiary-type structural change, compared to the probability of observing an agrarian economic structure.

The variable arable land per capita does not withstand various model specifications. Its increase reduces in models (1 and 4) and increases in models (2 and 3) the probability of observing a mutation of the economic structure polarised towards the industrial sector that has an intense economy in hand of agriculture work. This can be explained by landowners use of their spaces. Some may use them for agropastoral production, which will inflate the agricultural sector, relative to the industrial sector. On the other hand, others may use the space to construct industrial buildings or invest in real estate. In this case, the industrial sector increases relative to the agricultural sector. However, it is statistically significant.

The proxy variable of economic growth also has inconsistent effects on types of structural change. The improvement in the living conditions of the populations in models 2, 3 and 4 increases the risk of an economic structure more oriented towards the tertiary sector, relative to the agricultural sector. In model 2, the improvement in the well-being of the population is accompanied by an increase in the probability of observing an economy with an industrialised structure than an agrarian economy. This result corroborates those of table 10 which highlight the existence of unstable growth, accompanied by the expansion of the tertiary sector.

The proxy variable for institutional quality is robust to all specifications. Here, improving institutions is more likely to promote industrialisation than tertiarisation for a structurally underdeveloped economy. Similarly, Acemoglu et al. (2018) emphasise that democracy causes economic growth as it promotes better business climate. The model shows that good institutions promote industrialisation than tertiarisation of economic structures. This result is significant at the 1% level.

International openness, measured by the trade variable in the models, plays important role in promoting structural changes. The coefficients of the trade variable in random effects models become significant, unlike the estimates obtained by POMLOGIT. From REMLOGIT models 1–3, it is noted that a one percentage point rise in trade increases by 15–28% the risk of observing a structural change in the industrial type, rather than an agrarian economic structure. This result is consistent with previous findings (Kacou et al., 2022; van Neuss, 2019) Indeed, these authors suggest that trade openness stimulates and enhances the manufacturing productivity. In the same models, it is noted that the increase in international trade product increases by 2 to 3% the risk of observing a structural

change in the type of services, relative to structural underdevelopment. It falls in line with the resources curse hypothesis and contradicts the first effect just described (Kaba et al., 2022; Monga and Lin, 2019). Indeed, Monga and Lin (2019) justify that the significance of trade to enhance productivity of the service sector comes from the inability for African countries to convert their natural endowments into advantages as suggested by comparative advantage theory.

Attachment to resources, measured by variable mineral rent, has no statistically significant influence on structural change. However, it increases by 3% the chances of a tertiary economic structure occurring, relative to an agrarian economy. On the other hand, the mineral rent variable reduces by 23% the risk of observing a structurally industrialised economy relative to the risks of observing an agrarian economy. This result corroborates those of Kaba et al. (2022) and Kacou et al. (2022). They explain that the resource curse hypothesis also operates when countries' exports are mostly consisted of primary products. The latter is associated with low productivity, sticking thus the structural change process.

Coefficients var (RI2[c_id]) and var (RI3[c_id]) terms are the variances of random effects. In practical terms, these are the variances of idiosyncratic individual effects. The covariance is not significant, so it is not possible to conclude that there is a correlation between the two random intercepts. Moreover, the computed correlation remains at -0.0021, meaning there is a negative relationship between the two outcomes (Pope, 2014).

There has been an attempt to model the effects of mechanisation on types of structural change. The model estimates were inconsistent. The variable number of tractors and tractor density per kilometre are the best measures to capture agricultural modernisation (Daum and Birner, 2020; Huttunen, 2019). To understand its effect on the type of change, more analysis needs to be done, which is beyond the scope of the objective of this work.

b. Marginal effects

Figure 20 describes the relationships between the probability of observing one of the stages of structural change, and the expansion in agricultural land-use. The marginal effects obtained here are similar to those obtained in the POMLOGIT model.

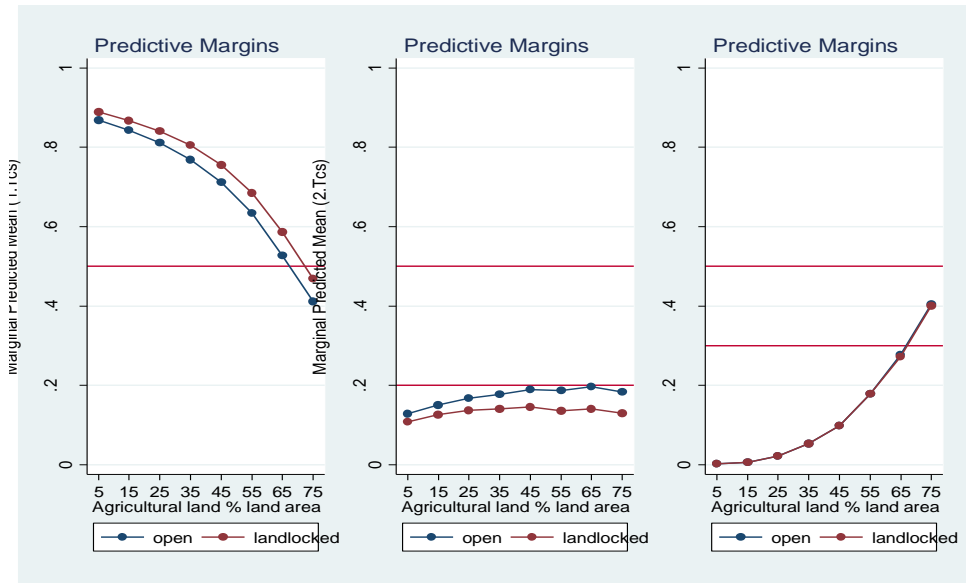


Figure 20: Margins after GSEM, random effects
Source: author.

It is noted that an increase in the land-use for agriculture is accompanied by a decrease in the probability of observing an agrarian-type economic structure (figure 20 on the left). This decrease happens at an increasing rate. Landlocked countries generally remain more agrarian than opened sea countries.

Then there is a timid increase in the probability of a change in the type of service following agricultural expansion. On average, landlocked countries develop a service economy more often than that of opened sea countries, consecutively to an increase in agricultural land. Finally, the likelihood of seeing a structurally industrialised economy is growing at an increasing rate as agricultural land expands. The model predicts, moreover, that the marginal effects are indifferent as to landlocked status. For this reason, the curves of countries with and without coastal openings are almost mixed up.

5.3.3.2. Varying the model specification: Fixed effects

This part introduces the results of the fixed effect model (FEMLOGIT). The period used for the estimation is 2004–2016. It is dictated by the convergence of the model and by the recommendations of the inventor of the technique (Pforr, 2019). The estimates interpreted in this subsection compare the coefficient estimates of the multinomial fixed-effects logit model to those of the multinomial random-effects logit model and the stacked multinomial logit model.

a. Global analysis of the model

The fixed-effect model that is estimated and interpreted in this subsection has acceptable statistical characteristics. A pseudo-R2 which culminates at 41%, which shows that the variables integrating

the model explain 41% of the variations of the dependent variable (TSC). Furthermore, Wald's global significance test, significant at 1% and amounts to a value $\text{Chi}^2 = 6367$ shows that the estimates are robust to the heteroskedasticity that may possibly be encountered (Wooldridge, 2010; Pforr, 2014).

Table 17: Effects of agricultural land expansion on stage of structural change: Fixed-effects

Period	POMLOGIT (Model 1) 1990 – 2016		REMLOGIT (Model 2) 1990 – 2016		FEMLOGIT (Model 3) 2004 – 2016	
	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed	Structurally Developing	Structurally Developed
Agricultural land	1.089*** (0.0294)	1.312*** (0.0931)	1.154*** (0.0346)	2.837*** (1.130)	0.664 (0.260)	3.184** (1.732)
Ag. land per cap	0.360 (1.710)	8.999 (26.26)	0.000684** (0.00200)	1.530 (17.65)		
Perm. cropland	0.771** (0.0830)	1.026 (0.199)	0.897 (0.0818)	0.331 (0.509)		
Governance	1.766*** (0.357)	14.67** (16.47)	3.596*** (0.870)	16.86*** (4,419)	29.01** (49.31)	191.8 (803.2)
Trade	1.005 (0.0110)	1.001 (0.0185)	1.032*** (0.00846)	1.275** (0.138)	1.065*** (0.0209)	1.316*** (0.0679)
Mineral rent	0.986 (0.0604)	1.155 (0.444)	1.030 (0.0414)	0.770 (0.197)	1.180 (0.250)	0.721*** (0.0552)
popgXagva	9.924** (10.88)	94,406*** (270,770)			2.06e-07*** (1.17e-06)	0.03*** (1.17)
aglXva	0.999 (0.000774)	0.988*** (0.00375)	0.998*** (0.000807)	0.971** (0.0141)		
GDP per cap	9.303*** (4.723)	0.0677 (0.111)	6.612*** (3.143)	0.00521 (0.0321)		
Pop. growth	0* (0)	0*** (0)	0** (0)	1.239e+103 (3.169e+105)		
Landlocked (1 if yes)	0.306 (0.254)	0.279 (0.637)	0.257 (0.288)	0.551 (2.311)		
Constant	1.95e-10*** (1.16e-09)	0.0801 (0.641)	5.76e-11*** (2.99e-10)	0 (0)		
var(RI2[c_id])			815.5*** (1,462)			
var(RI3[c_id])			7.645e+72 (9.873e+74)			
cov(RI3[c_id],RI2[c_id])			0.932 (2.198)			
Observations	690	690	690	690	143	143
R squared	0.577	0.577			0.431	0.431
K	24	24	28	28	10	10
N	41	41				
chi2	674.0***	674.0***			6367***	6367***

Robust seeform in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: author.

b. Analysis of variables

Table 17 discloses the results of the fixed effect model in the 3rd column. A good observation reveals that in that model, the coefficient of the variable of interest agricultural land expansion increases and multiplies by 2.18 the probability of observing a structural change of the industrial type. Indeed, this result attests to the fact that agricultural expansion increases the chances of an industrial-type structural change, relative to the observation of an underdeveloped economic structure. Robust result to various specifications and estimation techniques. In the 3rd same column, agricultural expansion

reduces by 33% the probability of observing an economic structure of the type of service, relative to an agrarian economic structure.

Despite the insignificance of the industrial-type structural change equation, the institutional quality variable also retains an expected effect on the types of structural change. It significantly increases the chances of an economy wherein employment is more concentrated in the service sector than in the agricultural sector. In addition, improving the quality of institutions also promotes an economic structure with a high concentration of industrial jobs relative to an agricultural concentration.

The foreign trade variable, captured here by *trade*, has the same effect on types of structural change. Instead of observing an economy dominated by agricultural jobs, a 1% increase in international trade will increase the chances of observing a tertiary-type structural change by 6%, while it increases the probability by 32% to observe an industrialised-type of structural change. This result is significant at the 1% level and in line previous studies (Baymul and Sen, 2020; Roy and Roy, 2017).

The fixed effects estimate reveals that the attachment to natural resources rent reduces by 28% the probability of observing an economic structure of the industrial type rather than an economy of the agricultural type. This result is similar to that obtained by Random Effects (REMLOGIT), whose explanation is recorded in the previous subsection.

The combined effect of agricultural value added and population growth is not robust to estimation methods. Using the technique of intra-variance, the simultaneous growth of agricultural value added and the population is accompanied by a reduction in the chances of observing a tertiary economic structure compared to an agrarian structure. It also significantly reduces the chances of observing an industrial economic structure, in favour of an agrarian economic structure. Some possible reasons for this fact are Africans' attachment to agricultural activities with low returns. First, cultural dimension of agriculture makes it a default activity and absorb rural populations when positive population and agricultural value-added shock arise. Populations are flocking more to agriculture or pastoral production activities to face demographic pressure as developed by Malthusian theory, which causes increases jobs in the agricultural sector. Second, poverty and food insecurity are best tackled by agricultural growth (Christiaensen and Demery, 2007). In addition, population growth increases the supply of employment in the agricultural sector. Then, simultaneous and positive shock of agricultural value added and demography will sound as a signal of resilience against poverty and food insecurity, causing a more agrarian economy.

6. Conclusion

The economic dimension of agricultural sustainability implies that overall product increases. During recent decades, sub-Saharan African countries have expanded their agricultural land and experienced an atypical structural transformation. The expansion of agricultural land is a source of long-term growth. However, the effects of agricultural expansion on structural change in Sub-Saharan Africa remains largely unknown. In this essay, investigations are made to understand the process of structural transformation and the effects of agricultural land expansion on the type of structural transformation in Africa.

The study covers the 1990–2016 period and focuses on 41 Sub-Saharan African countries. The dependent variable type of structural change (TSC) is constructed with three modalities: Structurally underdeveloped, structurally developing and structurally developed. The results are robust to different model specifications and estimation techniques likewise.

The results suggest that agricultural land expansion has a significant effect on structural transformation in the region. It is specified that it further increases the possibility for countries to have a predominantly industrial structure. The results are similar to those of Barbier (2019; 2020), Hornbeck and Keskin (2015), Eberhardt and Vollrath (2018) but diverge from those of Mensah et al. (2016), Martins (2019) and Johnson and Vollrath (2020). The reasons behind the results are the increase in land causing a more than proportionate increase in yields (Wise, 2020) which does not only release a surplus of production but also, a surplus of labour from the agricultural sector, to be captured by other sectors. Furthermore, the increase in production offers prospects for processing the agricultural surplus. Thus, producers who left the agricultural sector are more attracted to the secondary sector and motivated by the downstream diversification of their former activities. This increases the likelihood of observing a more industrialised economic structure. Hence the research null hypothesis that agricultural land expansion causes industrial-type of structural change in Africa cannot be rejected.

Overall, this essay shows that land expansion for agriculture is beneficial for ‘virtuous’ structural change, especially for the abundant land sub-Saharan. In addition, the quality of institutions is likely to encourage this same type of structural transformation. Moreover, the effects are faster when the two levers are activated jointly. In terms of economic policy recommendations, the following measures can be adopted to bring about an industrial-oriented type of structural transformation.

ESSAY III
EFFECTS OF AGRICULTURAL LAND EXPANSION ON BIODIVERSITY LOSS IN SUB-SAHARAN AFRICA

This essay has successfully received acceptance letters for two scholarships programmes. Pre-registration for a doctoral scholarship "Eugen Ionescu" at the Doctoral School, Faculty of Horticulture, Plant Protection Laboratory, "Ion Ionescu de la Brad" of IASI. Doctoral supervisor: Prof. Univ. Dr. Mihai TALMACIU

And

Pre-registration to the Coimbra Scholarship Programme, at the University of Cologne, Germany with Prof. Dr. Peter Dannenberg as research supervisor.

1. Introduction

Biodiversity conservation requires attention for two reasons. First, it provides a wide range of direct and indirect benefits for humans. Second, human activities contribute to unprecedented rates of biodiversity loss, which threaten the stability and continuity of ecosystems as well as their provision of goods and services to humans (Dasgupta, 2021; Markandya et al., 2008).

Human-induced biodiversity loss is greater now than at any time in human history (Kontoleon et al., 2008). Agricultural expansion causes 80% of forest area loss, which accelerates at a rate of 4 million ha each year (FAO, 2019). The expanding global economy coupled with an increasing human population poses a continuous threat to biodiversity (Sachs et al., 2009). As a matter of fact, an alarming 65% decrease in population sizes of mammals, fish, amphibians, and reptiles has been reported (Almond et al., 2020). Additionally, about half of the world's wildlife mammals and birds, could be on the verge of extinction by 2100 because of anthropogenic or human activities (Pimm and Raven, 2000; Sol, 2019).

Some of the causes of biodiversity loss are global warming and pollution (Dalgupta, 2021), populations and economic growth (Pagani-Núñez et al., 2022; Sol, 2019), agricultural land expansion (Molotoks et al., 2021; Perrings and Halkos, 2015; Tan et al., 2022), intensification (Kehoe et al., 2017), governance or institutional quality (Iritie, 2015; Muchapondwa and Stage, 2015; 't Sas-Rolfes, 2017), community protected areas (Ullah and Kim, 2021), habitat and land fragmentation (Conceição et al., 2022), trade and migration of species (Perrings and Kinzig, 2020).

The negative relationship linking agricultural land expansion and biodiversity poses a debate for two reasons. Some authors claim that agriculture could expand while coexisting peacefully with and supporting biodiversity. This is especially true in Africa, with 60 percent of the world's arable land, where there is an opportunity to do things differently (Almond et al., 2020; Darkoh, 2003). Contrarily, other authors posit that land fragmentation is a common feature of agricultural farmers, and those areas are positively associated with increasing threats to biodiversity (Markuszevska, 2013). Furthermore, the underpricing and underfunding of natural areas identified in sub-Saharan Africa exacerbate biodiversity depletion. The first increases the incentives to expand agricultural land at the expense of terrestrial biodiversity, while the second reduces the incentives to protect and preserve natural habits (Barbier, 2022; Dasgupta, 2021).

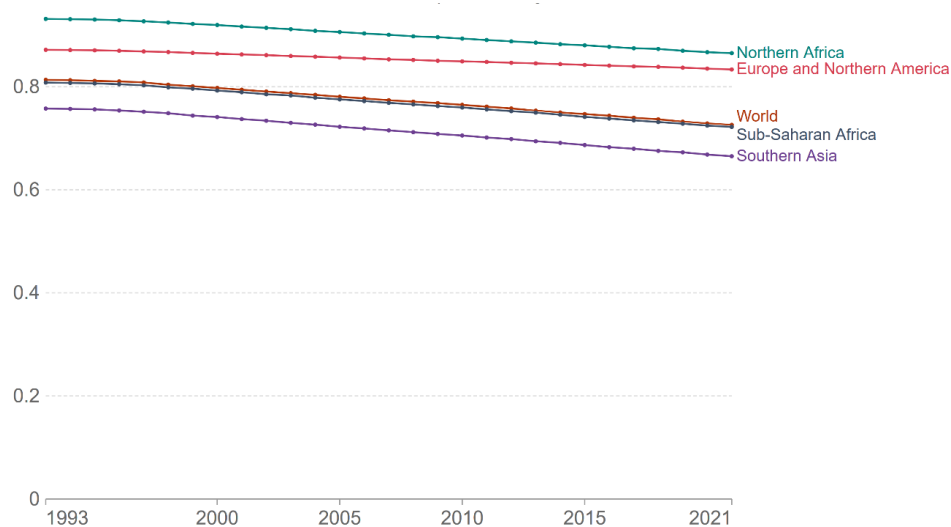
This essay aims at assessing the impact of agricultural land expansion on threatened species in sub-Saharan African countries. The rest of the essay is organised as follows: Section 2 reviews the literature; Section 3 exposes the methodology of the study; Section 4 analyses and interprets the results; and finally, Section 5 concludes the essay.

2. Stylised Facts on the Biodiversity status in Africa

The presentation of the main trends in biodiversity proceeds in two stages: starting with a comparative description of the evolution of biodiversity conservation in different regions of the world and further focusing on the analysis of how biodiversity status is going in sub-Saharan Africa.

2.1. Evolution of the extinction risk of species in the world

To analyse the rate at which biodiversity is changing, many indicators can be used, among which the Red list index⁷ albeit imperfect.



Source: Birdlife International and International Union for Conservation of Nature

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Figure 21: Redlist Index

The Red List Index (RLI) defines the conservation status of major species groups and measures trends in the proportion of species expected to remain extinct in the near future without additional conservation action. When the RLI value equals 1.0, all species are classified as ‘Least Concern’, and hence none are expected to go extinct in the near future. However, a value of zero indicates that all species have gone extinct.

From figure 21, it is seen that globally and for all regions of the world, trends in the state of biodiversity have a negative shape. From the figure, two groups can be identified. The first part is comprised of Northern Africa, Europe, and Northern America. These regions had RLI values close to 0.9 in 1993, which declined to around 0.85 in 2021. This depicts a slight decrease, especially in Europe and Northern America, with a reduction of less than one percentage point of evolution. Low pressure on land used for agriculture, mastery of agricultural technology, and low relative abundance

⁷ Other measures are presented in the methodology section of the present essay.

of species can conjointly explain the flatness of their curves as compared to those of regions in the second group.

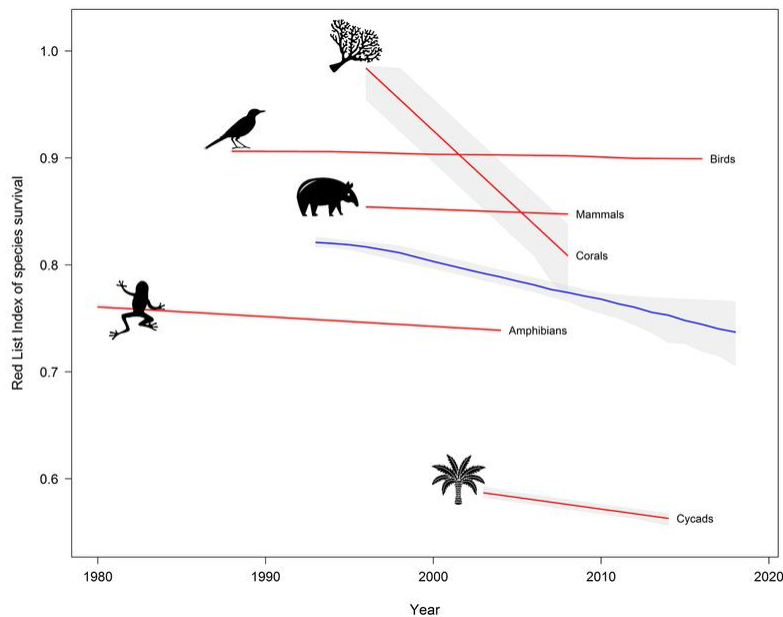


Figure 22: Redlist index for groups of species
Source: BirdLife International and IUCN (2021)

The second group is composed of tropical regions. They are known to be very abundant in species, but with a rapid decline in their RLI. In 1993, Sub-Saharan Africa's RLI value was 0.8, while Southern Asia showed 0.77. The new values are 0.7 for the former and about 0.63 for the latter. This means that biodiversity in these regions is more threatened, and species suffer a higher risk of extinction. The reduction of more than one percentage point of the RLI can be explained by at least two factors: the rate at which populations grow and the rate at which natural environment areas are depleted. This causes a reduction in different species.

2.2. Evolution of groups of species

Most species that move between categories on the IUCN Red List do so because of improved knowledge or revised taxonomy. It is not possible to determine any meaningful trends in the status of biodiversity simply by looking at overall changes in the numbers of threatened species between updates. For this reason, the statistics for numbers of threatened species in each IUCN Red List since 1996 must be interpreted with extreme care; these figures illustrate increasing assessment efforts to refine current understanding of the status of biodiversity rather than showing genuine status changes over time.

Currently, the RLI is available for five taxonomic groups only (those in which all species have been assessed at least twice): birds, mammals, amphibians, cycads, and warm-water reef-forming coral (Figure 22). The RLI clearly demonstrates that the status of these major groups is still declining. The

blue line indicates the overall RLI for all the taxa combined. It shows the general level of threat for all groups. Coral species are moving towards increased extinction risk most rapidly as their indicator value declines by almost 2 percentage points, going from 0.98 to 0.8 in about 10 years since 1999. It can be seen that amphibians are, on average, the most threatened animal group, with a RLI of about 0.6, with little variation between 1980 and 2005. It is also noted that, on average, birds are the least threatened group of species from 1990 to 2020, as their RLI value is constant at around 0.9. They are followed by mammals. The divergences between threats can be correlated to their respective natural habitats. As a matter of fact, human activities such as crop cultivation may hurt both birds and amphibians, as forests may host varieties of the said species (Ahrends et al., 2015). However, amphibians have two natural habitats, which make them twice as exposed as other species.

2.3. Some facts on biodiversity in Africa

Tropics are generally less diverse in terms of species, genera, and families of plants. The African mainland has between 40,000 and 60,000 plant species, of which approximately 35,000 are endemic (Mutke and Barthlott, 2005). There is a great deal of diversity and endemism in aquatic life in isolated lakes and large river systems. Primates, insects, and birds are most prevalent in forest regions, while ungulates and large carnivores are most prevalent in savannah regions. Isolated mountain regions are home to many rare endemic species. Other species, such as the African elephant, have a broader habitat use and are widespread across the continent. A quarter (1229 species) of the world's approximately 4700 mammal species are found in Africa, including 960 in sub-Saharan Africa (SSA) and 137 in Madagascar. They contain over 2000 bird species, nearly a fifth of the approximately 10,000 bird species in the world (De Klerk et al., 2004). About 1600 bird species are endemic to SSA (de Klerk et al., 2002; Kinzig and McShane, 2015).

Three reasons justify the choice of Sub-Saharan African countries for the study: First, the severe biodiversity loss, particularly in mammals and birds, coincides with high poverty rates in Sub-Saharan African countries (Sachs et al., 2009); second, over the last twenty years, community-based interventions have been widely used in Sub-Saharan Africa as mechanisms to combine rural development and conservation efforts (Brooks et al., 2004; Lindsey et al., 2007; Martins et al., 2018); third, Sub-Saharan African countries share similar characteristics in terms of biodiversity richness and species diversity (Ullah and Kim, 2021).

3. Literature review linking agricultural land and biodiversity loss

This section shows different theoretical explanations and reviews empirical studies on biodiversity loss as a result of agricultural land expansion.

3.1. Expansion of agricultural land and biodiversity change: Theoretical Background

Three approaches explain the ways in which agricultural land expansion is linked to biodiversity change in literature: protectionist, extensive marginal, spatial, and temporal approaches.

3.1.1. Agricultural land expansion and biodiversity change: a protectionist approach

From the perspective of environmental protection approaches, Pigou and Coase's theories of protection-measures can explain the link between agricultural expansion and biodiversity loss.

3.1.1.1. Pigouvian externalities from agricultural land expansion

Following Marshall (1890), Pigou (1920) was interested in the issue of externalities, i.e., the consequences of economic activity that are not accounted for in prices. Externalities can be positive or negative. He understood that economic activity could have an impact on agents who do not participate in the bilateral market relationship. When an industry pollutes, it negatively disrupts the life and activity of its neighbour without having to compensate the neighbour for the damages incurred.

In economics, an externality is said to be negative when an agent is responsible for a social cost greater than the private cost imposed on him for the damage he causes. The role of the state is to levy a tax equivalent to the difference between these two costs (the Pigouvian tax). This is referred to as the "polluter pays" principle. The advantage of this policy is twofold. On the one hand, it reduces negative externalities by sending a clear and understandable signal to the market. On the other hand, it generates tax revenue for the state (Belpaire, 2013).

The economic activity of agricultural production on increasingly large areas can lead to the destruction of natural capital (mammals, birds, amphibians, reptiles, and plants). This wildlife often has cultural values for the indigenous populations of the Americas and especially of sub-Saharan Africa. Destroying these elements of biodiversity leads to the disruption of the beliefs, traditions, rites, and religions of these populations. Worse, it can lead to claims and uprisings. A Pigouvian tax is a means of deterring or redressing crimes against biodiversity and the people who are culturally connected to it.

3.1.1.2. Coase property rights to prevent agricultural land sourcing biodiversity loss

In his theorem, Coase (1960) posits an alternative solution to environmental preservation that dispenses with public intervention to create a market for environmental damage. It states that if property rights can be properly defined, if the sender and the victims of the externality are rigorously identified, and in the absence of transaction costs (i.e., valuation, negotiation, or similar costs), then the affected parties can negotiate of their own free will and thus fix a price for the damage. The damage or environmental impact then becomes an economic good that can be traded on a market. Under these conditions, it is possible to find an optimal allocation of resources in accordance with the individual preferences of the agents without the intervention of the state. All decisions become private, and the problem loses its public nature.

Coase's theorem seems to be misinterpreted as an apology for the privatisation of natural spaces and a criticism of state intervention. On the contrary, Coase's argument is to show the importance of transaction costs. The theorem shows that if these negotiated solutions do not exist in the real world, it is because transaction costs are present and determine in a fundamental way the inefficiency of arrangements between parties. For Coase, individuals are constrained by a series of social, legal, or institutional norms that do not always fit the neoclassical model.

It is interesting that, in Coase's view, substantial state intervention and fresh institutional arrangements to enhance coordination between interdependent agents can justify the existence of transaction costs. In this sense, Coase is much more interventionist than Pigou. In fact, Coase (1960) believed that everything in the business world was random, so it was necessary to consider the function of institutions in the economy. Roughly speaking, in the case where economic activity is perfectly influenced by the legal framework, Coase (1992) recognised that the usefulness of government intervention would be limited to the clear definition of property rights, considering an efficient economic system without externality (without transaction costs).

According to Coase's reasoning, the expansion of agricultural land can be liberal but regulated by a functioning market with state intervention. The definition of property rights could help to responsibly increase agricultural land at the expense of natural habitats. This would make it possible to simultaneously take into account the problems of static coordination and regulation and dynamic coordination, centred on exhaustible natural resources, and intergenerational equity.

To conclude, if protection measures are not well defined or respected, agricultural land expansion and other human economic activities are expected to damage the environment. This is the case for

sub-Saharan African countries; hence, we may expect a negative relationship between the two variables.

3.1.2. Agricultural land expansion and biodiversity change: an extensive margin approach

Increasingly, the extensive growth of farmland areas poses threats to many animals and nature as a whole.

3.1.2.1. The Ricardian theory of diminishing returns and biodiversity loss

The law of diminishing returns, developed by David Ricardo (1817), is a concept that has been applied to agriculture. It states that agricultural returns fall as land is cultivated to meet the needs of an ever-increasing population. This law states the principle that the marginal productivity of land decreases, all else being equal.

Drawing on Malthus, Ricardo compares land to a series of machines for producing wheat and raw materials. Each machine is imperishable and indestructible. Nature is inexhaustible, but the fertility of the land decreases as the population and its food needs increase. Agricultural yields, therefore, decrease as the population increases; the best land being used first, according to Ricardo, becomes less and less efficient. On this note, he states: ‘There is no rent at the outset when the pioneers arrive in a fertile region where the land is abundant and only a small portion is necessary to feed the population, or, moreover, that only a small portion can be cultivated with the capital available to the population.’ Indeed, no one is willing to pay for an abundant good that is unappropriated and, therefore, available to everyone who wants to use it. With each increase in population, which forces a country to exploit inferior land in order to increase food production, the rent on fertile land will increase.

In the long term, land is a variable factor, and due to decreasing yields from primary land, new space will be needed for agricultural production. As a result, there will be an increase in pollution and the expropriation of wildlife from its living environment. This leads to biodiversity loss and the depletion of natural resources.

In a similar vein, J. S. Mill (1848) held that agricultural land expansion damages natural beauty. Here, natural beauty is understood as the environment in all its diversity. Irrespective of the time span, it is expected from Mill’s point of view that the expansion of agricultural land will deplete natural resources, bringing pollution and biodiversity threats.

3.1.2.2. Kuznets Environmental Curve: Agricultural growth and biodiversity loss

Neoclassical economic theorists argue that environmental quality is a luxury good and, therefore, only affluent societies are willing to heavily invest in environmental protection. The environmental Kuznets curve (EKC) is the statistical hypothesis that describes this expected relationship between affluence and environmental quality (Kuznets, 1955).

The existence of technical and natural capital was assumed. The exploitation of the natural capital, which is land, to produce economic goods leads to the exhaustion of natural resources, increasing their price. The reduction in natural capital should be compensated by the increase in available quantities of technical capital. The latter must increase at the same rate as the rent from exploited and limited resources.

The model assumes the absence of technical progress and that adequate investments can enhance sustainable development as long as capital is available. Grossman and Krueger (1995) hold this upbeat view of development. They show that environmental degradation and GDP have a quadratic relationship.

The EKC hypothesis suggests that environmental problems follow an inverted U-shaped curve relative to affluence (typically measured as GDP per capita), where environmental problems escalate in the early stages of development, but eventually a tipping point is reached, after which further economic growth leads to improvements in environmental quality.

According to the environmental Kuznets Curve (EKC) theory, there is a close relationship between agricultural land and biodiversity depletion. Agricultural crops or livestock are produced using both technical and natural capital. The natural capital here is the agricultural land, forests, or wetlands about to be converted for agriculture. In the absence of technical progress, producing greater agricultural output requires more land conversion, as land is natural. Consequently, many species lose their natural habitat and may face extinction. In the absence of technical progress, production increases so as to satisfy the economic agent's needs. No more land expansion is needed, and this reduces, in relative terms, the extinction rate of species. Here, it is the extensive growth of agricultural output that has caused the biodiversity loss.

3.1.2.3. The environmental sociology ecological modernisation theory

This theory parallels the EKC argument. The main difference is that it is not focused on a single economic development argument. The environmental sociology ecological modernization theory (EMT) suggests that, although nations may alter the environment in the early stages of modernisation, the later stages of modernisation are accompanied by the emergence of 'ecological rationality', where

environmental concerns diffuse throughout society, leading to the restructuring of major political, economic, and social institutions along ecologically sustainable lines (Clausen, 2008). From the EMT perspective, instead of economic development, it is rather the institutional changes that accompany modernisation, such as the development of scientific organisations and the ongoing "rationalisation" of bureaucracies, that lead to environmental reform and protection.

Although the scale of economic production is one indicator of the modernisation of institutions, some scholars suggest that urbanisation is particularly pertinent as an indicator of the institutional restructuring that is integral to the modernisation process (Ehrhardt-Martinez, 1998; Ehrhardt-Martinez et al., 2002). This leads to the hypothesis that environmental impacts may follow an EKC related to urbanisation.

Ehrhardt-Martinez et al. (2002) suggest that such a relationship is likely to exist for direct impacts on the land, such as deforestation (and, by implication, species endangerment as well), because urbanisation concentrates people in cities, reducing population density in natural habitats and the number of people who are dependent for their livelihoods on direct extraction of natural resources.

According to Bren d'Amour et al. (2017), urban expansion generally hurts croplands. They claim that sub-Saharan African countries experience the greatest percentage loss of croplands, while Asian countries experience the highest absolute loss of croplands due to urbanisation. Consequently, the 'ecological rationality' of people would emerge more as the loss of croplands would call upon the conversion and dedication of areas for agriculture at the expense of formerly secured species.

From this approach, obvious biodiversity loss comes from agriculture, with some turning points. However, the work omits to consider the possible existence of such relationships because they go beyond its objectives.

3.1.3. Spatial economics approaches

From a spatial perspective, either land rent or displacement effects account for the ways in which agricultural land expansion increases threats to biodiversity.

3.1.3.1. The land rent theory of natural habitat destruction

Among natural habitats, forests have a richer biodiversity. Von Thunen (1826) developed a land value framework for natural habitat destruction, focusing on the case of forests. The main idea of this spatial economic theory of land is that a piece of land should be allocated to the use that would generate the highest potential rent (Chomitz and Griffiths, 1996; Von Amsberg, 1994). In summary, by assuming profit maximisation motivation, competition among land uses will be determined by which land use yields the highest land rent or value, as illustrated in figure 23 in the next page:

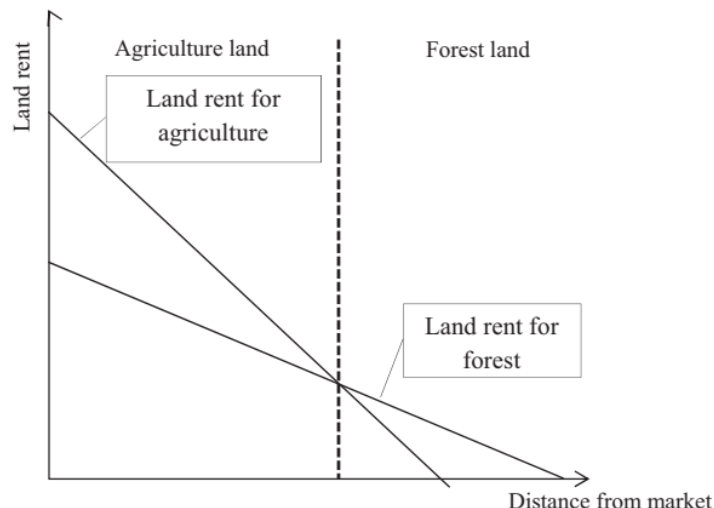


Figure 23: Model for land rent for natural habitats: Case of deforestation
 Source: simplified from von Amsberg (1994)

The key to explaining changes in land uses and land cover is changes in land rent for different uses (Angelsen, 2007; Hyde et al., 1996). Particularly, forest as another natural habitat could be conserved when land use for forest can generate the maximum value compared to other possible land uses. On the other side, forest or prime land preservation could be encouraged on a given land if its land use for being reforested or conserved can compete with other land uses. In the case of competition between agriculture and forest land uses, as described in figure 23, forest land use will start to take place in the location (dotted line) where the rent for forest land is higher than that of agriculture. The use of forest land for agricultural purposes could increase the expected value of that use.

3.1.3.2. Displacement Effects of agricultural land and natural habits losses

This development is found in Slingenberg et al. (2009). Direct land use changes are, for all the challenges they present, broadly understood according to their effects on the environmental impacts of biofuel production. However, indirect land use change, also known as displacement effects, is perhaps the most daunting, complex, and consequential aspect of increasing biomass production globally.

In figure 24, Y is the new demand from the biofuel sector from existing plantations. X refers to the expansion of existing plantations as a result of displacement effects. Displacement effects may occur when the production of energy crops displaces economic activities in other areas, causing environmental degradation as a result of the new activity (in this case, biomass production). These effects can range from local to larger and more complex global consequences.

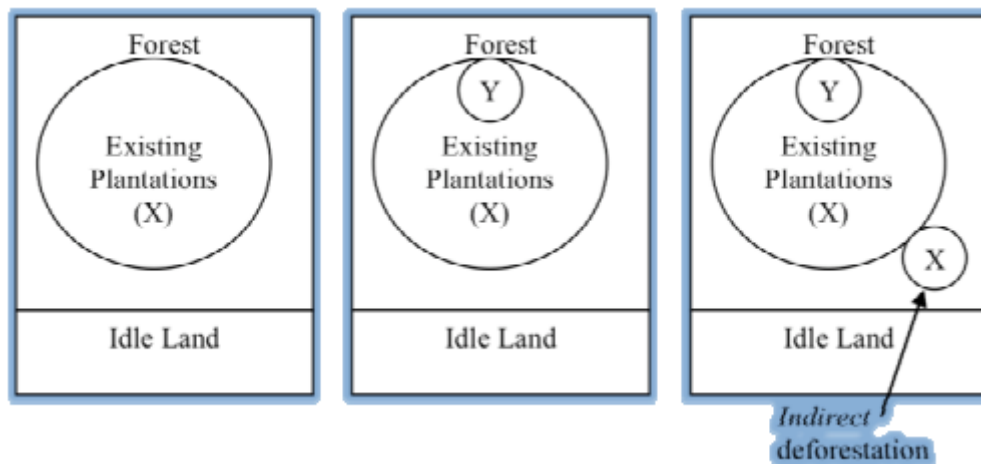


Figure 24: Example of land displacement mechanism causing indirect deforestation
Source: Slingenberg et al. (2008).

If, for instance, a soy plantation was previously used primarily for food purposes and converted the same production to energy crops, then that same demand for food from soy would have to be met elsewhere in the long run. In the short run, prices of foods derived from soy would rise. The conversion of soy plantations from food to energy will spark the supply of soy plantations for food elsewhere. Consequently, higher pressure for expanding land use for agricultural production will increase, heightening the risk of environmental degradation.

This approach shows that agricultural land expansion will cause biodiversity loss because of the benefit of rents or indirect deforestation.

3.1.4. Agricultural land expansion and biodiversity loss debate: Temporality approach

According to the timelessness of natural resources, the contradicting theories analysing the relationship between agricultural land expansion and biodiversity loss are exposed: the atemporal theory of natural resources and the temporal theory of natural resources.

3.1.4.1. The theory of the atemporality of natural resources and agricultural expansion

A priori, natural resources are infinite and free. They belong by right to all individuals in a nation and are perceived as a public good whose stock is not limited. The most explicit text on this subject is by Frédéric Bastiat, on coal: *‘Newcastle coal is lavished gratuitously on all men; it is lavished gratuitously on them like water from the stream, on the sole condition that they fetch it or return the trouble to those who take it for us. When we buy coal, it is not the coal that we pay for, but the work that had to be done to extract and transport it’* (René, 1996).

For Bastiat, the true measure of value is the service rendered. Coal, like all other natural resources, has no value because it is unlimited in quantity. Their value is the same as the value of the digging,

extraction, and distribution necessary to make them available on the market. The existence of markets allows agents to substitute the purchase for the effort of doing. This effort sets the price levels of goods and services, whether they are market or non-market (Daniel, 2010).

In his analysis, Bastiat opts to deny the intertemporality of the allocation of natural resources. Such a conception fully legitimises agricultural expansion and highlights the denial of the harmful effects of the latter on biodiversity. In this context of infinite resources, agricultural expansion is likely to reduce biodiversity without any concern.

This conception of free natural resources is unrealistic because it considers the stock of natural resources to be infinite. Additionally, the value lost to future generations as a result of the decline in land stock is significant. Moreover, the increase in cultivable land immediately comes up against the conservation and preservation of habitats and natural environments, which are by default singular. Hence, the main idea of this work, which radically and fundamentally confronts this theory of the timelessness of natural resources.

3.1.4.2. The Hotelling temporal theory of natural resources and agricultural land expansion

However, there is another view of the finiteness of natural resources that justifies the fact that the rate of depletion and exhaustion of these resources is lower than their rate of regeneration. Natural resources are limited, and both current and future generations must use them, according to Hotelling (1931). Structural expansion is a support ramp for present generations; it would be an obstacle to the preservation of natural resources. From the activities of the present generation, the problem of access to natural resources for future generations may arise. The author's work makes explicit this dynamic conception of the use of natural resources.

Nature provides resources, but, depending on the jurisdictions in force, they are appropriable. Then, in response to the 'conservationists,' according to whom the price system does not allow for a rational management of natural resources, Hotelling makes it possible to define, for the owner of a stock of goods that diminishes as it is exploited, a rule for maximising the present value of his profits over a finite time horizon. This rule can be formulated as follows:

The owner of a deposit has two options at any given time: either extract one more unit today, sell it, and invest his gain, or leave his deposit fallow, wait a certain amount of time, and later sell the extracted unit on the market.

The optimal rate of exploitation of the resource is given by the equalisation of the market price and the marginal cost of production, to which is added a scarcity rent expressing the finiteness of the stock

and therefore the unavailability of the resource in the future. On this basis, the operator has an interest in extracting as long as his marginal cost is not greater than his marginal revenue (quantity (Q) x selling price (P));

The cost of the natural resource and the rent associated with it must rise at a rate equal to the interest rate (or discount rate), making the preservation of the resource on the site equivalent to its extraction and the investment of the sale proceeds with interest.

According to this rule, the total volume of a resource constitutes a rent for the owner that justifies a price increase beyond the marginal costs. This scarcity rent therefore distinguishes the exploited natural resource, whether renewable or not, from other goods or services, but in doing so, it is assimilated into capital and implies its appropriation. In its absence (e.g., deep-sea fishing), companies are not interested in the optimal management of a free, i.e., non-appropriable, resource and will seek to exploit it at a frantic pace, possibly exhausting it.

In relation to agricultural land expansion, there are two possible scenarios. First, land expansion occurs either consecutively or independently of natural resource extraction. In the first case, agricultural land expansion does not cause the destruction of biodiversity or has mitigation effects. This is because the scarcity rent exploited first has a higher value than the secondary agricultural product for the owner. In the second case, the agricultural land increase causes the complete destruction of natural habitats and species. The agricultural product is the primary product and has a higher value than the natural resources or biodiversity, which is the secondary product.

In both cases, it is still possible that agricultural expansion poses serious conservation problems for natural areas and species. While present or current generations may feel the first signs of natural resource deprivation only slightly, future generations will feel the brunt of natural resource loss. This study hypothesises the latter relationship in the context of sub-Saharan Africa.

3.2. Expansion of agricultural land and biodiversity change: Empirical literature

In this subsection, we consider studies that link, on the one hand, the expansion of land for agriculture and biodiversity and, on the other hand, those relating how agricultural expansion destroys natural habitats.

3.2.1. Land expansion for agriculture affects species biodiversity

In his latest publication, Barbier (2022) links agricultural land expansion and terrestrial biodiversity loss with two policy failures. The underpricing and underfunding of nature The underpricing of nature implies that when the price of natural areas is too low, it leads to agricultural expansion. Indeed, natural areas are converted to agriculture, forestry, and other land uses at a lower cost than protecting

or preserving habitats. This narrative study bequeaths a better place to Tan et al. (2022), who use a negative binomial regression model to confirm that agricultural land expansion increases threats to faunal biodiversity in South and Southeast Asian countries. However, both the important reserves of agricultural land and significant improvements in area protection raise questions about the land expansion and biodiversity loss nexus in Africa, which this study seeks to clarify.

Markuszczyńska (2013) finds that among the few positive aspects of the expansion of agriculturally fragmented land, there is increased biodiversity in the areas affected by this phenomenon. Bulte and Horan (2003) build a model where farmers have the option of either hunting for wildlife or growing crops. They later conclude that different patterns of conservation and agricultural expansion may emerge and that greater conservation may be consistent with higher incomes.

To understand the effects of cropland expansion on biodiversity loss, Phalan et al. (2013) analysed data on crop distribution and expansion in tropical countries. They find that areas of high potential for cultivation may be vulnerable to conversion in the future. These include some priority areas for biodiversity conservation in tropical countries that have previously been identified as having 'low vulnerability,' in particular in central Africa and northern Australia.

Zabel et al.'s (2019) purpose is to investigate the biodiversity consequences of attaining equal global production gains by 2030, either by cropland expansion or intensification. With the aid of a Computable General Equilibrium analysis, their results suggest that production gains will occur at the expense of biodiversity, predominantly in developing tropical regions, while Europe and North America benefit from lower world market prices without putting their own biodiversity at risk.

Ahrends et al. (2015) analyse the subsequent spread of land conversion to monoculture rubber plantations and its impact on biodiversity and livelihoods. They conclude that expansion into marginal areas creates a clear potential for loss-loss scenarios, such as the clearing of high-biodiversity-value land for a crop that is poorly adapted to local conditions and, by altering landscape function while not producing long-term sustainable yields, may ultimately also compromise livelihoods.

Kehoe et al. (2017) carry out research on the effects of expansion pathways and intensification on biodiversity using a Cobb-Douglas model. The authors find that 30% of species richness and 31% of species abundance are potentially lost because of agricultural expansion across the Amazon and Afrotropics. Only 21% of high-risk expansion areas in the Afrotropics overlap with protected areas (compared with 43% in the Neotropics). Areas at risk of biodiversity loss from intensification are found in India, Eastern Europe, and the Afrotropics region (7% species richness, 13% abundance

loss). In a similar way, Dobrovolski et al. (2013) conclude that incorporating future agricultural expansion resulted in a lower representation of carnivore species, as the average proportion of the range represented reduced from 58% to 32%.

Medan et al. (2011) summarise for the first time the effects of agriculture expansion and intensification on animal diversity in the Pampas of Argentina. His systematic review suggests that birds and carnivores are more strongly affected than rodents and insects, but responses varied within groups: the geographic ranges or abundances of many native species were reduced, sometimes leading to regional extinction; other native species were unaffected (birds) or benefited (birds, rodents, and possibly generalist pollinators and crop-associated insect species); while novel species were introduced, thus increasing the species richness of most groups (26% of non-rodent mammals, 11.1% of rodents, 6.2% of birds, and 0.8% of pollinators).

Using a carbon model, Chaplin-Kramer et al. (2015) examine the impact of different spatial patterns of agricultural expansion on biodiversity. They find that for the same amount of land conversion, the declines in biodiversity and carbon storage can vary from two to fourfold. In addition, impacts increase most rapidly in the earliest stages of agricultural expansion, are more pronounced in scenarios where conversion occurs in forest interiors, and are most destructive when they occur in a fragmentary pattern rather than in a consolidated patch.

Perrings and Halkos (2015) assess the effects of agricultural expansion and intensification on threats to endemic species in sub-Saharan Africa. Using a country-level approach, they find that over longer time scales, agricultural intensification has offered conservation benefits in Sub-Saharan Africa. However, they found little evidence that intensification reduces threats to biodiversity on shorter time scales. On the other hand, the extensive growth of agriculture is associated with increasing threats to biodiversity at all time scales.

Foley et al. (2015) found that global croplands, pastures, plantations, and urban areas have expanded, accompanied by large increases in energy, water, and fertiliser consumption, along with considerable losses of biodiversity. Such changes in land use have enabled humans to appropriate an increasing share of the planet's resources, but they also potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases.

Evans and Potts (2015) develop an integrated econometric-ecological modelling framework that examines the impact of changing prices for agricultural commodities on grassland bird abundance in the United States. They use ecological models that predict changes in species abundance for twenty-

two grassland birds in response to land use change. They show that a relatively inelastic total cropland acreage responds to expected prices, mitigating some of the ecological impact arising from increased demand for agricultural commodities.

Kietzka et al. (2018) assessed the effects of local agricultural and urban land transformations on Odonata species richness and assemblage composition in three rivers. Land transformation significantly influenced Odonata assemblage composition but did not always significantly reduce species richness. Agricultural and urban local land use types reduced opportunities for some endemic species but provided for the persistence and establishment of widespread, generalist species, as indicated by great changes in DBI scores.

Ullah and Kim (2021) evaluate the conservation effects due to changes in the size of community-governed protected areas (PAs) with a synthetic control method and difference and difference. Their analysis concerns SSA countries from 2000-2016 and findings suggest that countries with community-governed PAs have reduced the International Union for Conservation of Nature (IUCN) Red List threat level by 17% for mammals. In addition, they also find stronger evidence of the effect of community-governed PAs on the IUCN threat level using the synthetic control method that allows them to match the 'intervention countries' with those countries that exhibit similar preintervention threat levels.

Delzeit et al. (2017) examined whether potential conversion to cropland would affect areas of high biodiversity value or conservation importance. Using a CGE model, they find that the expansion of cropland generally results in improved food security, not only in regions where crop production rises. On the other hand, the estimated cropland expansion could take place in many highly biodiverse regions. However, Sol (2019) shows analyses 557 regions of the globe with econometric estimation on that species extinction increases with population density and GDP per capita. The causal links and the author's findings suggest that the conservation of nature requires degrowth, or at least a transition to a steady-state economy, because the growth of agricultural areas will hurt biodiversity.

The loss of biodiversity from biomass production is another central factor to be considered in the production of biofuels. Biomass production on previously 'idle land' (as opposed to crop substitution) may lead to biodiversity loss. Thus, the conversion of areas with high biodiversity, such as rainforests and peatlands, to the production of biomass results in the loss of habitat and ecosystem services, and most importantly, the capture of carbon. In addition, the use of pesticides and genetically modified crops may also endanger wildlife and biodiversity.

Changes in landscape due to such activities as agriculture, urban sprawl, and transportation infrastructure are generally recognised in the literature as major causes of the loss of biodiversity. Urban sprawl, for example, affects land change elsewhere through the transformation of urban-rural linkages. Given that urban lifestyles tend to raise consumption expectations and that 60% of the world's population will be urban by 2025, the rural-urban linkage, or the urban 'ecological footprint,' is critical to land change assessments.

To identify the priority threats to biodiversity in sub-Saharan Africa, Leisher et al. (2020) classified the direct threats to biodiversity. They find that the highest threats are annual and perennial crops (non-timber), despite the fact that within the sub-regions of sub-Saharan Africa there is considerable variation.

3.2.2. Land expansion and effects on natural habitats

Agricultural land expansion can have effects on many natural habits. As it expands rapidly through the conversion of forests, wetlands, and other natural habitats (Barbier, 2004a). Moreover, in all tropical regions of the world, the principal result of agricultural land expansion is deforestation (Barbier, 2004b).

Ngoma et al. (2021) revealed that cropland expansion by smallholders into forests represents about 60% of the estimated 250,000 ha of forests lost per year in Zambia. Similarly, Delacote (2007) tried to address the impact of the use of forest products as safety nets by poor agricultural households on deforestation and showed that the household is better off and deforests less when using the diversification strategy instead of the coping strategy.

Oliveira et al. (2013) use simulations and scenarios and find that expansion of agriculture in Amazonia may be a no-win scenario: in addition to reductions in carbon storage due to deforestation, total agriculture output may either increase much less than proportionally to the potential expansion in agricultural area or even decrease as a consequence of climate feedback from changes in land use.

Similarly, Fitzherbert et al. (2008) assess the contribution of palm oil to tropical deforestation and review its biodiversity. They use a map analysis and find that for both biodiversity and native tropical forests, oil palm plantations are a poor substitute. They support a few species of conservation importance and affect biodiversity in adjacent habitats through fragmentation, edge effects, and pollution.

Moraes et al. (2017) provide an analysis of the agricultural expansion and its impact on a protected area located in Brazil using map accuracy. They show that the landscape patterns were affected by economic cycles. The forest fragmentation process and the predominance of monoculture lands in the

buffer zone threaten the protected areas and can represent a barrier for these areas to provide effective biodiversity conservation.

Conversely, Zeng et al. (2018) found that large increases in cultivated areas have evolved from forests that vary in health and status, including primary and protected forests, or from recovering lands that were on a trajectory to become secondary forests in South Asia. Equally, they found that cropland expansion reduced species' natural habitats. Similarly, Ordway et al. (2017) draw the same conclusion while assessing the effects of domestic- and export-oriented agricultural expansion on deforestation in SSA. They claim that commodity crop expansion is increasing exposure, vulnerability, and pressures on natural habits and species diversity. Similarly, Gaveau et al. (2016) conclude that plantation industries have been the principal driver of deforestation in Malaysian Borneo for up to four decades. In contrast, their role in deforestation in Indonesian Borneo was less marked. Gibbs et al. (2010) examine whether new agricultural lands replace forests, degraded forests, or grasslands, which greatly affects the environmental consequences of expansion. Their results suggest that across the tropics, more than 55% of new agricultural land came at the expense of intact forests, and another 28% resulted from disturbed forests. In addition, Kløverpris (2009) indicates in his results that agricultural expansion on land suited for crop cultivation (cultivable land) typically affects forest biomes or potential grassland or steppe, whereas expansion on land suited for grazing but not for crop cultivation typically occurs on potential shrubland or a few other biomes depending on the region.

Other studies relate land expansion to other natural habits. In a recent study, Balima et al. (2020) used principal component analysis found that tropical West African savannah ecosystems protected areas hold higher species diversity than agricultural lands. Hence, land use pressures shrink plant species diversity in tree biomass. Working in marginal lands, Kraemer et al. (2015) mobilise land-use change simulations and find that cropland expansion during the Virgin Lands Campaign was significantly associated with favourable agro-environmental conditions. They concluded that the potential for cropland production in currently uncultivated areas is much lower than commonly believed, and further cropland expansion is only possible at the expense of marginal lands.

Laurance et al. (2014) assess how the required increases in food and biofuel production will affect tropical terrestrial and aquatic ecosystems and biodiversity. They find that the goals of a well-nourished global population and healthy ecosystems are inextricably linked, that the already-massive global footprint of agriculture is expanding rapidly, and that its impacts on terrestrial and aquatic ecosystems will be intense and increasingly pervasive, especially in Sub-Saharan Africa and South America. Tilman (1999) investigates the environmental costs of agricultural ecosystems that are

better at producing food and yielding more efficient yields. Findings suggested that the forecasted largest impacts would be on freshwater and marine ecosystems, which would be greatly eutrophied by high rates of nitrogen and phosphorus release from agricultural fields.

Similarly, Xin et al. (2021) characterise the temporal dynamics of estate crop expansion into natural forests in Indonesia. They conclude that the effectiveness of protected areas decreased over time and became insignificant. Moreover, estate crop expansion via land-cover and land-use change trajectory hopping would severely threaten biodiversity because it tends to occur in lowland forests, diminishing natural habitat area and increasing natural forest isolation.

There are inconclusive studies of the relationship between agricultural land expansion and biodiversity. Firstly, Minde et al. (2001) examine the potential that some of the macroeconomic policies under structural adjustment programmes (SAPs) have for increased agricultural land expansion. Although they indicate that land for agricultural production is obtained from the forests, the surveys did not link crops to this 'new' agricultural land. This means that agricultural land expansion was unable to cause biodiversity loss.

Secondly, Darkoh (2003) establishes that the relationships could be reciprocally beneficial. In all regions of Northern Africa, the West African Sahel, East Africa, the Horn, and Southern Africa, agriculture accelerates the loss of biodiversity because of attempts by farmers to increase crop and animal production to feed the increasing population and contribute to the growth of the national economies. However, they mention that agriculture and biodiversity can be complementary activities. If properly managed, agriculture should enhance and not be the enemy of biodiversity in the drylands of Africa.

Thirdly, Fenta et al. (2020) measure what loss in ecosystem services value (ESV) is caused by land degradation. They concluded that land cover change resulted in a net increase in the total ESV of US\$125 billion, albeit with an ESV loss of US\$60 billion per year from the conversion of evergreen forest and shrubland. Overall, cropland expansion accounted for about 60% of the increase in the total ESV, thereby outweighing the decrease in ESV due to the decline in natural vegetation.

Most of the studies reviewed here use map analysis and consider biodiversity from the viewpoint of natural habits to investigate how agricultural expansion causes biodiversity decline indirectly. This study diverges from theirs in that it explores the direct links while accounting for the number of species threatened and uses econometric regressions to find causation links.

4. Methodology of analysis of the effects of agricultural expansion on biodiversity loss

This section presents specifications regarding the study's empirical model and data sources are.

4.1. Nature, data sources and scope of the study

This essay provides empirical validation of the effects of agricultural land extension on biodiversity conservation. The data used are from secondary sources. To capture biodiversity, the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (2016) database is used. Economic variables are drawn from the World Development Indicators (WDI, 2019). The latter reports agricultural land variables as well. Meanwhile, the variables on governance and institutions are from the World Governance Indicator (WGI, 2020), and data on protected areas comes from the World Database of Protected Areas (2020).

Due to data availability, the dataset mobilised by the study covers a first set of 12 countries and a second set of 31 countries for a 3-year period. The IUCN Red List of Endangered Species contains assessments of extinction threat levels for both plant and animal species based on population size, habitat range, and estimated extinction risk. This study uses the 2013-2, 2014-2, and 2015-2 versions that contain assessments categorised as either least concern, data deficient, vulnerable, endangered, near threatened, critically endangered, extinct, lower risk/conservation dependent, or extinct in the wild. In the majority, the assessments are carried out by the IUCN Species Survival Commission, and all assessments are reviewed by a member of the Red List Authority on the relevant taxonomic group (Sol, 2019).

The World Database of Protected Areas is the fruit of a joint initiative between the United Nations Environment Programme (UNEP), the World Conservation Monitoring Centre (UNEP-WCMC), the IUCN, and the World Commission on Protected Areas (WCPA). It is the largest database that gathers, compiles, and reports data on marine and terrestrial protected areas (PAs) in collaboration with various governmental and non-governmental organisations, academia, and industry. Its aim is to develop and maintain an accurate and freely available, up-to-date database on PA status around the world to be used as a global standard by all relevant stakeholders (Brook et al., 2004).

In the WDPA database, the governance of PAs has many sub-categories. These include PAs established by the government; areas established under regional and international conventions; privately owned conservation areas; and areas conserved by indigenous people and local communities. The IUCN has two further broad types of classifications: (1) management categories and (2) governance types. The protected area management categories help us classify PAs based on their primary management objectives (Dudley, 2008), while the governance types classify PAs according to who holds authority, responsibility, and accountability for them (Borrini et al., 2013). Currently, about 65% of the PAs in the WDPA have an IUCN management category, and 88% have

governance types (Deguignet et al., 2014). In this essay, the latter classification is used because it sufficiently reports the extent to which authority, responsibility, and accountability are devolved to the lower level in terms of resource use (Ullah and Kim, 2021).

4.1.1. Measures of biodiversity change

To measure biodiversity, the existing literature suggests many indicators. Roughly 100 different indicators are proposed for the Aichi meeting of the Convention on Biological Diversity (CBD) (Pereira et al. 2013). Recognising this complexity, Pereira et al. (2013) developed a framework of Essential Biodiversity Variables (EBVs) that could form the basis of monitoring programmes worldwide. EBVs are designed to help prioritise indicators by seeking to define a minimum set of six⁸ broad essential classes to capture major dimensions of biodiversity change.

Despite the extensive work, the methodology employed by Pereira et al. (2013) was found to be complex. Subsequently, for simpler measures, Mace et al. (2018) suggested three key indicators to understand change in biodiversity, which are useful when considering trajectories to international biodiversity targets and would adequately capture key dimensions of biodiversity (essentially extinction risk, abundance, and composition):

- (1) Conservation status: estimating near-future global losses of species (extinctions), which can be measured using the IUCN Red List Index (RLI).
- (2) Population trends: trends in the abundance of wild species that can be measured using the Living Planet Index (LPI).
- (3) Biotic integrity (community composition): This can be measured using the Biodiversity Intactness Index (BII), which measures the fraction of naturally present terrestrial biodiversity that still remains.

4.1.1.1. The IUCN Red List Index

The RLI is developed from experts' assessments of species using information on life-history traits, population and distribution, size and structure, and their change over time (IUCN, 2020). Red List assessors classify species into one of the eight categories (extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, least concerned, or data deficient). Over 100,000 species have now been assessed. The Red List Index uses this data to show trends in survival probability over time (Butchart et al., 2007). It is only available for five taxonomic groups that have had repeated assessments: birds, mammals, amphibians, corals, and cycads, although species

⁸ See Dasgupta Review (2021)

assessments are being updated all the time. This is the measure used in this study to capture biodiversity loss, focusing on birds and mammals' taxa.

The IUCN Red List is a globally recognised approach for assessing and monitoring the status of biodiversity. The scientific objectivity of the IUCN Red List is assessed through the categories and criteria developed in 1994 and revised in 2001. According to this criterion, there are nine categories: extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, least concern, data deficient, and not evaluated. Every surveyed species falls into one of these categories. So far, the IUCN has developed quantitative criteria for three categories: critically endangered, endangered, and vulnerable (Ullah and Kim, 2021). Species listed within each of these categories are believed to share a similar probability of extinction. Species falling into the categories of critically endangered or endangered and vulnerable are collectively described as 'threatened' and are generally used as a measure of threat to biodiversity. Consistent with IUCN classification, our measure of biodiversity loss in a country is the number of mammals and bird species known to be threatened from 2013 to 2015. These two taxonomic groups have been comprehensively assessed since 2000. Previous studies that have used this measure include country-level studies (Perrings and Halkos, 2015; Sol, 2019) and panel studies (Ullah and Kim, 2021).

4.1.1.2. The Living Planet Index

The Living Planet Index (LPI) is a measure of the state of the world's biological diversity based on population trends of vertebrate species from terrestrial, freshwater, and marine habitats. The LPI is based on trends for over 4,000 species and thousands of population time series collected from monitored sites around the world (Almond et al., 2020). Species groups are chosen based on data availability. The species population data that is collected goes into a global index as well as indexes for more specific biogeographic areas, referred to as realms, based upon distinct groupings of species. The extent to which this index can be disaggregated depends on the quantity and resolution of the data. For example, there is no LPI for countries like the United Kingdom. Due to the absence of such data for SSA countries, the index cannot be used in the study.

4.1.1.3. The Biodiversity Intactness Index

The Biodiversity Intactness Index (BII) represents the fraction of naturally present biodiversity still remaining in terrestrial ecological communities in a region (Scholes and Biggs, 2005). The BII aims at using taxonomically and geographically representative data and consequently includes considerable amounts of insect and plant data, unlike the LPI and the RLI. The BII considers the impacts of land use, land use intensity, and other pressures, such as human population density and proximity to roads, in a modelling framework (Purvis et al., 2018). It does not include climate change

impacts, fails to distinguish between plantations and natural forests, and does not account for the delayed effects of land use change. The index, therefore, is not in line with the study's interest.

4.2. The baseline model and description of variables

To assess the effects of agricultural land extension on biodiversity, the study formulates and estimates a model of biodiversity threats. Assuming that people have preferences for agricultural and other goods and services, as well as the biodiversity that supports those services. Additionally, they implicitly weigh the benefits of agricultural growth against the costs of biodiversity loss.

Thus, economic agents make a liberal trade-off between reducing the abundance of weeds, rodents, pests, and other pathogens and increasing the abundance of other species of their choice. Following Perrings and Halkos (2015), we abstract from the complexity of the problem by assuming that the benefits of biodiversity can be separated into those that contribute directly to income and those that do not. The latter are constituted of cultural services, which reflect the totemic, religious, or cultural values attached to individual species, landscapes, or ecosystems.

Undoubtedly, many reasons explain why actual resource use may differ from socially optimal resource use, including ignorance or fundamental uncertainty about the consequences of particular actions, the displacement of the costs of actions in space or time, the structure of property rights, the ineffectiveness of mechanisms for the governance of resources in the public domain, externalities, and the public good nature of many ecosystem services (Perrings and Halkos, 2015). Nevertheless, as a first approximation, the assumption that decision-makers have some awareness of the factors to be balanced in growing the agricultural sector is reasonable.

To account for this, the following theoretical social utility function, U_{it} , is proposed:

$$U_{it} = F(Y_{it}(K_{it}, L_{it}, P_{it}, S_{it}), S) \quad (\text{eq10})$$

Where Y_{it} denotes the goods and services supporting consumption and investment, K_{it} denotes nonagricultural assets (capital), L_{it} denotes agricultural assets (land), P_{it} denotes human resources (population), and $S = \sum_j S_j, j = 1, \dots, n$ refers to the set of species in all countries that affects social utility (biodiversity).

That is, it is assumed that in a particular year, people derive both direct, $U_{it}(S_{it})$, and indirect, $U_{it}(Y_{it}(S_{it}))$, benefits from biodiversity.

For the optimum to occur in country i , the change in biodiversity associated with a change in other assets should balance the marginal utility of the goods and services generated by those assets when evaluated in terms of the marginal direct and indirect utility of biodiversity (Perrings and Halkos, 2015). In other words, if the growth of agricultural assets and other forms of capital causes a decline in biodiversity, then the value of the goods and services created in the process should be at least as great as the value of the lost biodiversity.

To match the model formulation with a panel dataset, the base-line model is expressed as follows:

$$\ln TS_{it} = \alpha_0 + \alpha_1 \text{aland}_{it} + \beta_{it} X_{it} + \varepsilon_{it} \quad (\text{eq11})$$

Where TS_{it} is the measure of biodiversity threat captured by the threatened species, aland_{it} is agricultural land in percentage of total area of country i in year t , and X_{it} is the set of other control variables for country i in year t , which are presented in the variable justification subsection.

Although there are no perfect measures of biodiversity change, dTS_{it} , the most commonly used measure is the number of species designated as threatened in the IUCN Red List (IUCN 2014). Some potential difficulties with the Red List as a measure of biodiversity change are illustrated in the literature. It does not yet provide operational data on rates of change in the number of threatened species. Revisions in the basis on which estimates are made mean that estimates for different years are still not comparable. In addition, different levels of reporting effort mean that the series is likely to suffer from measurement error due to selection bias (although this is likely to affect the estimated model coefficients less than their standard errors) (Boakes et al., 2010; Butchart et al., 2007; Hilton-Taylor et al., 2009; Possingham et al., 2002; Rodrigues et al., 2006).

As a result, the study chose to employ two alternative proxies, each of which consisted of the natural log of the total number of endemic species in a country's taxonomic categories for both mammals and birds. The number of vulnerable species in both the taxonomic groupings of mammals and birds is used as a response variable for the robustness check.

4.2.1. Justification and expected relationships of variables with biodiversity change

The portion of the earth's surface covered by arable land, perennial crops, and perennial pastures is referred to as agricultural land. According to theoretical and empirical literature (Perrings and Halkos, 2015), the loss of biodiversity is anticipated to rise as a result of the development of agricultural land. This indicates that in all three models, a positive coefficient is anticipated.

Additionally, the area of land planted with cereal (measured in hectares; Lnland) is used to assess the stability of the relationship between biodiversity and widespread agricultural growth. As a result, the study anticipates a direct relationship between the two factors.

The intensive growth of agriculture is taken into account and measured by the agriculture value added per worker (agvapw) in 2010 in constant dollars. Consistent with Perrings and Halkos (2015), the intensive growth of agriculture should reduce biodiversity loss. There is then an expectation of a negative sign of the variable intensive growth.

The Gross Domestic Product per capita (lngdpcap) is used to evaluate the biodiversity effects of economic growth. Perrings and Halkos (2015) found that an increase in the annual return on all capital stocks in a country, or Gross National Income (GNI) per capita, raises threats to biodiversity. However, as Sol (2019) a negative relation between lngdpcap and risk of extinctions of species is hypothesised. i.e., more prosperous regions have more means for conservation or outsource their polluting activities. Demographic factors are measured using two variables: population density (popdens) and population growth (lnpop). Both variables are introduced in our models. According to the literature (Perrings and Halkos, 2015; Sol, 2019; Ullah and Kim, 2021), demographic factors are either unrelated or negatively related to biodiversity loss. The study agrees with that conclusion in the case of population density. However, because of the high poverty level in sub-Saharan Africa, an increase in population will pose threats to biodiversity.

Governance or institutional variables used in this essay include rule of law (rle) and the composite index of governance (Gov). The introduction of both variables is inspired by literature. According to previous studies, governance can have two different effects on biodiversity. In some cases, when all governance/institutional indicators are improved, it may reduce the risk of species extinction. On the contrary, improving a single indicator of governance, like the rule of law, can increase the risk of species extinction (Iritié et al., 2015).

Ullah and Kim (2021) reveal that countries with community-governed protected areas have reduced the IUCN Red List threat level by 17% for mammals. The study consecutively includes protected areas (pa) in the model, and its coefficient is expected to have a negative sign. This is to show that protected areas expressed as a proportion of total areas are efficient at reducing threat levels to biodiversity.

Finally, a dichotomous variable, "landlocked," is included in our model. This helps to assess if the openness of the sea reduces the risk of a threat to biodiversity. Landlocked countries are expected to have lower threats to biodiversity than sea-opening countries.

The variables included in the baseline model, as well as their expected signs, are summarised in Table 18 below.

Table 18: Variables and expected signs to threats to mammals

Short names	Full names	Expected signs
aland	Agricultural land	+
lncland	Cereal land (in log)	+
araland	Arable land	+
permland	Permanent land	+
agvapw	Agricultural	-
lngdpcap	Gross domestic product per capita	+
popdens	Population density	+
lnpop	Population growth	+
gov	Governance	-
rle	Rule of law	+
pa	Protected areas	-
1=landlocked	Landlocked countries (<i>1 if yes, 0 if no</i>)	-

Source: author

4.2.2. Estimation strategy

The Population – Averaged approach (PA) or Pooled Feasible General Least Square (PFGLS) is used to estimate the model. The database mobilised by the study covers a first set of 12 countries over a 3-year period and a second set of 31 countries over the same time span. This is an improvement, as Perrings and Halkos (2015) and Sol (2019) used only a single time period to measure how agricultural land expansion relates to biodiversity loss. They used generalised least squares (GLS) on country-level studies. The authors' common reasons why their respective studies cover only one year are that the IUCN database is reassessed more than once within a year, and some species may be included in later versions but not in earlier versions. As a result, data on threatened species are not comparable from one year to another.

Contrarily to the previous study, Ullah and Kim (2021) carried out a panel study with available panel data exclusively delivered by the IUCN office. The latter study justifies the current one, which covers only the 2013–2015 period. During this time period, data are available and purged of some discrepancies. The estimation technique used to analyse this model is the population-averaged (PA) approach, which is the best fit for such short panels of data (Cameron and Trivedi, 2009).

One contribution of the current study is its methodological aspect. Indeed, it uses a population-averaged (PA) approach, which is also known as the Pooled Feasible General Least Square (PFGLS). Standard errors need to adjust for any error correlation, and given a model for error correlation, more

efficient FGLS estimation is possible (Cameron and Trivedi, 2009). As a matter of fact, this approach assumes that any individual effects are random and are averaged out. The estimators simply regress response variables (Y_{it}) on an intercept and the set of explanatory variables (X_{it}), using both between-section and within-time series variation in the data. Hence, the estimation technique brings into the analysis temporal information that has not been considered by recent literature.

Estimating a model with the population-average approach requires specifying restrictions on error correlations. Let $\rho_{ts} = Cor(U_{it}, U_{is})$, the error correlation over time for individual i , and note the restriction that ρ_{ts} , does not vary with i . The STATA corr options all set $\rho_{ts} = 1$ but differ in the model for ρ_{ts} for $t \neq s$. Correlations structures used in the study include: (i) independent which means $\rho_{ts} = 0$ for $t \neq s$ which makes population-averaged approach equivalent to Pooled Ordinary Least Square estimators, and (ii) stationary at level (1) to use a moving average – MA (g) process. Here $\rho_{ts} = \rho_{|t-s|}$ if $|t - s| \leq g$, and $\rho_{ts} = 0$ if $|t - s| > g$ is considered. Other error correlation restrictions include autoregressive, exchangeable, unstructured, and non-stationary. They are better explained in Cameron and Trivedi (2009).

The robustness analysis is made up of the following steps: First, the Pooled Feasible Generalised Least Square (PFGLS) for long panels is used to account for plausible heteroskedasticity and cross-sectional correlations in the panel. Then, we use alternative measures of agricultural land expansion, namely arable land and permanent land, to assess the contribution of those types of land expansion to biodiversity threats in Africa.

5. Results and discussion

The results section, presents the descriptive statistics of variables, a graphical illustration and the estimated results of our interest relationship.

5.1. Descriptive statistics of variables

To keep descriptive statistics light, table 19 only presents statistics of response variables as well as interest variables.

Table 19: Descriptive statistics

	Mammals Endemic	Birds Endemic	Mammals Total	Birds Total	Agr. land	Cereal Land	Arable land	Permanent land	Protected area
Count	143	143	107	107	134	134	134	134	140
Mean	3,83	2,64	17,50	16,91	48,36	13,31	39,83	39,81	49,01
Median	0	0	13	14	47,14	13,97	37,54	38,36	48,36
Min	0	0	2	5	3,37	5,87	8,85	3,87	0
Max	114	28	116	45	79,83	16,6	36,68	89,43	100
Sd	14,49	5,09	16,73	8,85	20,96	2,28	26,78	10,61	27,81

Source: Author

Descriptive statistics are presented in table 19 above. Information is given for both endemic species and non-endemic or total species threatened. For each endemic taxonomic group, there are great differences between the mean and the median. The median for mammals and birds is zero, while their mean stands at almost 4 and 3, respectively. Looking at the total number of threatened species, similar differences with endemic species are recorded. Means are greater than medians. An average of almost 18 against a median of 13 for mammals, and an average of 17 for birds compared to a median of 14. The results are in line with those of Perrings and Halkos (2015). A highly asymmetric distribution of data is suspected. The standard deviations show that mammals (endemic and total) distributions have higher levels of disparity than birds' distributions.

The red list index variable displays a lower median than the average. The mean risk of a threat to biodiversity is 0.87. In some countries, the lowest level of biodiversity conservation stands at 0.42, while the conservation level of biodiversity equals 0.99 in other countries. The small value of the standard deviation is 0.1. This may be due to the nature of the variable, which is a proportion.

In the sample, the average land expansion rate is 48.36%, which is very close to its median of 47.14%. The maximum expansion rate is 79.8%, compared to the minimum of 3.37%. The standard deviation is 20.96, which demonstrates a high disparity of distribution around its mean. The cereal land variable shares almost the same characteristics as cereal land.

The surface under protection in the sample has an average of 49,000 Km². The median is almost equal to and displays 48,360 km². However, there is a great dispersion around the mean, as the standard deviation is 27.81. Moreover, some countries have zero km² of protected area in the sample,

while others dedicate up to 100,000 km² of land for biodiversity protection. These statistics are slightly different from what the literature provides (Ullah and Kim, 2021).

5.2. Graphical analysis agricultural land expansion and biodiversity loss

In this section, a graphical analysis of the relationship between extensive agricultural growth and biodiversity loss is provided. This analysis is done in two steps: First, the presentation of the effects of the increase in agricultural land on endemic species, and second, the assessment of the impact of the increase in agricultural land on the total number of threatened species in the countries.

5.2.1. Agricultural land and endemic species threats

Figure 25 illustrates the relationship between endemic species and agricultural land expansion. The researcher analyses both mammals (figure 25a) and birds (figure 25b) taxonomic groups and finds positive relationships.

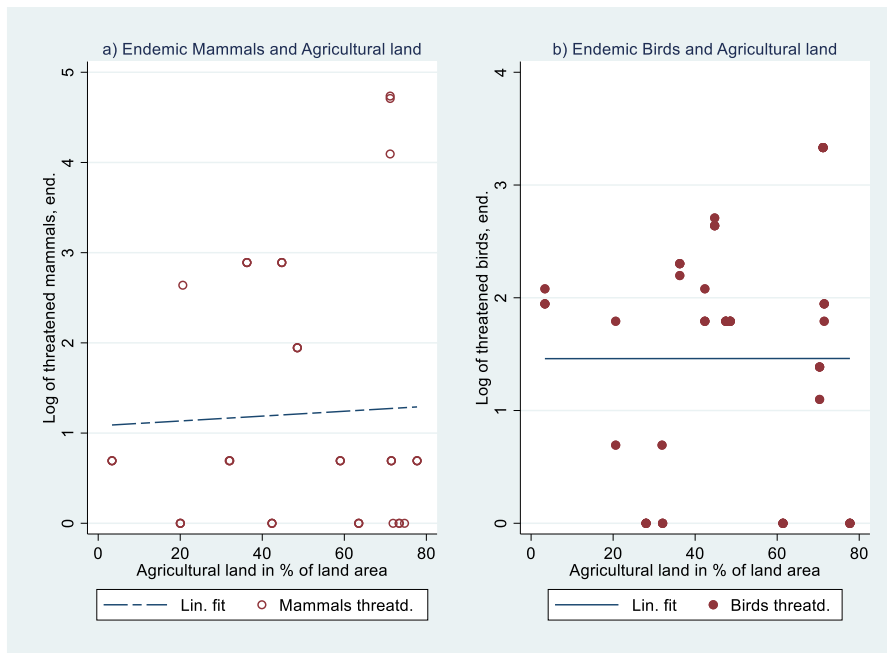


Figure 25: Agricultural land expansion and endemic species

Source: author

From the first figure (25a), it appears that the expansion of agricultural land poses important threats to endemic mammals. The adjustment curve has a positive slope, showing that there is a direct relationship between agricultural land expansion and threats to endemic mammals. In other words, low percentages of land dedicated to agriculture are associated with low levels of threats to endemic mammals. As the land is converted for agricultural purposes, threats to endemic mammals also increase. Finally, there are high percentages of agricultural land coupled with a high number of threatened endemic mammals.

Looking at figure 25b, it is observed that a similar positive relationship between agricultural land and the number of endemic birds is threatened. Where land is moderately dedicated to agriculture, a small number of endemic bird species are threatened. However, threats increase as more land is used for agricultural activity. This confirms the literature on this topic, which explains that the extensive growth of agriculture causes a high risk of species extinction.

It is also important to note that the graphs show dissimilarity. While comparing the figures, evidence shows that the slopes of the curves are different. The adjustment line for endemic mammals is sharper than that for endemic birds. Expanding agricultural land will lead to a greater risk of loss for endemic mammals than endemic birds. Therefore, increasing agricultural land is risky for both taxonomic groups and for species occurring in one country only. But the threat is more dangerous for mammals than for birds.

5.2.2. Agricultural land and total species threats

Figure 26 shows the relationship between arable land and three taxonomic groups: mammals (Fig. 26a) and birds (Fig. 26b). From the first sub-figure, we can discover a positive relationship between the variables.

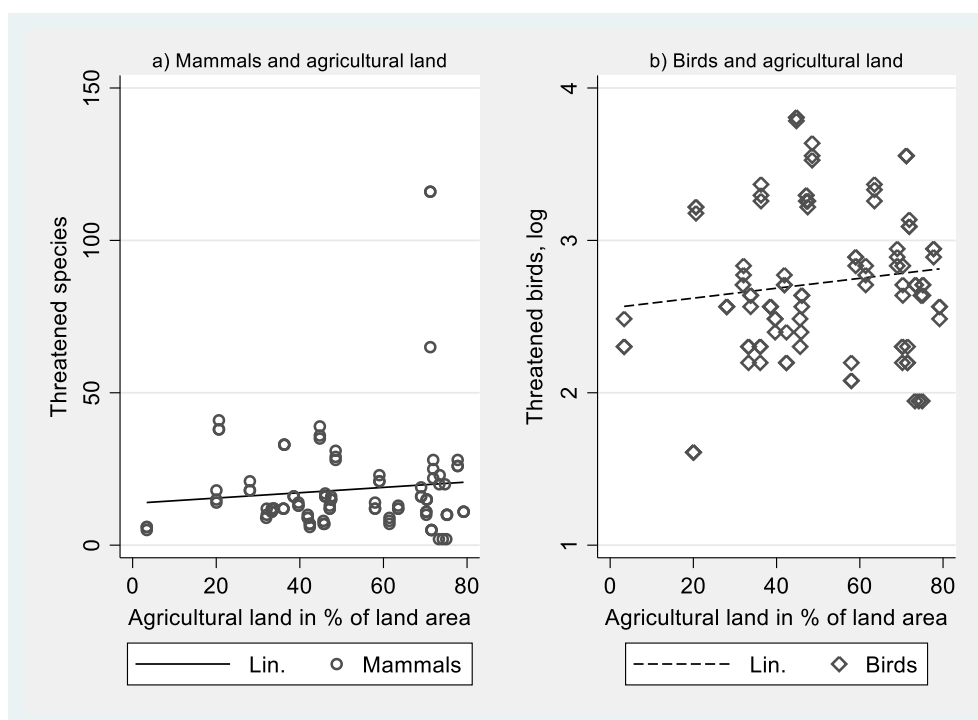


Figure 26: Agricultural land expansion and total species
Source: author

This was the case with endemic mammal species in the previous section. As land is progressively transformed for agricultural purposes, the threat to mammals rises and becomes more and more important. Hence, the greater the expansion of agricultural land, the greater the risk of mammal

species extinction (Fig. 26b). From the first sub-figure, we can discover a positive relationship between the variables. This was the case with endemic mammal species in the previous section. As land is progressively transformed for agricultural purposes, the threat to mammals rises and becomes more and more important. Hence, the greater the expansion of agricultural land, the greater the risk of mammal species' extinction. This should be justified by the fact that increasing land for agriculture leads to the natural habitat loss of mammals.

When looking at threatened bird species in the second sub-figure, a positive relationship with the agricultural land surface is also identified. As countries devote more of their available land to agriculture, bird species are endangered. The slope of the adjustment line shows a steady and strong direct relationship. Hence, expanding agricultural land will not only be risky to endemic species; it will certainly cause damage to overall bird species.

This section has permitted us to establish the relationship between the extensive growth of agriculture and biodiversity loss. The graphical analyses showed that no matter the taxonomic groups in this study, pressures from land expansion are perceptible. Evidence of such positive links exists irrespective of how they measure biodiversity, that is, both endemic and total species.

5.3. Econometric results

5.3.1. Baseline results

Table 20 displays two bunches of models of two taxonomic groups. Firstly, the estimated coefficients from both endemic mammals and birds' models (endemic models), and secondly estimated coefficients from total threatened mammals and birds' models (total models). The coefficients are produced by the population-averaged method of estimations. This method of estimation indicated for short panels.

The general analysis of the table shows that all the coefficients together are statistically different from zero with high Chi squared values (409–585). This goodness-of-fits show that the estimations of the four models can be used for policy design and forecasting. Individual analysis of the variables goes in line with consistent results suggested by the global analysis. Indeed, most of the variables are significant at 10% threshold.

The variable of interest, agricultural land expansion, is significant in all four models. The expansion increases the risk of extinction of threatened species whether endemic or not. In endemic models (columns 1 and 2), a 1 percentage point increase in land devoted to agriculture causes a 5% increase in the risk of mammal extinction. A one percentage point increase in agricultural land causes a 0.9%

increase in the threat to bird species. The coefficients are significant at the 1% and 5% levels respectively.

When analysing the non-endemic models (columns 3 and 4), the same direct relationship between land expansion and the threat to biodiversity is noted. Indeed, the threat increases by 0.7% and 0.2% for mammals and birds respectively, following a 1% increase in land dedicated to agriculture. These results are significant at the 5% and 10% level respectively.

Table 20: Agricultural land and biodiversity loss

Dependent variables	(1) Endemic Mammals	(2) Endemic Birds	(3) Total Mammals	(4) Total Birds
Agricultural land	0.0543*** (0.0104)	0.00958* (0.00455)	0.00670** (0.00781)	0.00214* (0.00256)
Cereal land (log)	1.069*** (0.174)	-1.132*** (0.0820)	0.218*** (0.0514)	-0.230*** (0.0272)
Intensive agriculture	-0.000389*** (0.000101)	-0.000549*** (6.32e-05)	-0.000184*** (6.89e-05)	-0.000158*** (4.07e-05)
GDP per cap (log)	-2.083*** (0.328)	-0.943*** (0.187)	0.00364 (0.172)	0.136* (0.0764)
Population density	-0.0310*** (0.00532)	0.0370*** (0.00336)	0.00432*** (0.00165)	0.00310*** (0.000744)
Population growth (log)	2.369*** (0.558)	-3.269*** (0.362)	-0.313** (0.128)	-0.196*** (0.0627)
Governance	-2.456*** (0.238)	0.437 (0.306)	-0.852*** (0.238)	-0.260** (0.115)
Rule of law	9.317*** (0.739)	0.422 (0.813)	2.530*** (0.719)	0.999*** (0.335)
Protected areas	-0.0371*** (0.00712)	-0.0349*** (0.00389)	-0.000338 (0.00390)	-0.00401*** (0.00147)
1.landlocked (1 if yes, 0 if no)	0.0817 (0.394)	-2.406*** (0.190)	-1.218*** (0.260)	-0.671*** (0.107)
Constant	38.87*** (3.848)	2.223 (3.243)	7.816*** (2.826)	1.740 (1.152)
Observations	36	35	93	93
Number of id	12	12	31	31
chi2	409.3***	585.1***	88.90***	132.4***

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author

The explanation for this phenomenon is that the use of land for agricultural purposes causes the destruction of the species' natural ecosystems (mammals and birds). This results in the destruction of their natural habitats, which leads to overpopulation in other, more or less safe places. This facilitates the capture of species for game consumption or display as hunting trophies. These results converge with those in the literature (Perrings and Halkos, 2015; Sol, 2019).

The second variable, a cereal land, also increases the risk of mammal species not surviving. The coefficients are all significant at the 1% level. This result is constant whether the model is endemic

or non-endemic (columns 1 and 3). The analysis of the mammal models (columns 1 and 3) shows that a one-percent increase in cereal land leads to a 1.06% ($\exp(-1.07)-1$) increase in the threat to endemic mammals and to a 0.21% increase in the risk of extinction of total mammals. This result is intuitive and expected. Cereal production is central to the food self-sufficiency goals of African countries. Africa needs to produce one billion tonnes of cereals per year to satisfy its population growth in 2050 (FAO, 2014). The finding is a reminder of the antagonism between achieving the objective of food security in Africa and the objective of biodiversity conservation. The finding converges with that of Sol (2019), who shows how agricultural expansion can accelerate the extinction of wildlife species.

In the case of birds (columns 2 and 4), it leads to a 1.13% decrease in the threat of extinction for endemics and a 0.23% reduction in total birds. This may result from the fact that cereal production is advantageous for birds and provides them with enough food to threaten their survival. The finding diverges from Perrings and Halkos (2015) and Tan et al. (2022).

The variable intensive agriculture measured by agricultural value added per worker (agvapw) maintains a negative relationship with the biodiversity proxies, although its effect is significant at the 1% level in all domains. Indeed, a small increase in the loss of endemic species' ability to capture biodiversity results from an increase of one dollar per worker. On the other hand, there is a negative and expected effect in columns 2–4. Indeed, intensive agriculture results in a very small decrease (less than 0.001%) in the loss of biodiversity and the disappearance of endangered species.

The explanation attributed to this result is that poverty and subsistence are intimately linked to threats to biodiversity. Increasing agricultural productivity and the incomes of producers, in turn, will generate a shift in their utility curve and reduce the amount of game hunted. In addition, the expansion of agricultural land will be slowed down, and fewer species will be threatened.

This result is similar to that obtained by Perrings and Halkos (2015), who show that agricultural intensification is associated with reduced biodiversity loss for all species in the long term. Moreover, it is shown that, in the short term, this relationship can be verified. In other words, agricultural productivity growth reduces biodiversity loss.

The economic growth variable (lngdpcap) is highly significant and negative in the endemic models (1–2) and positive in the non-endemic models (3–4). It is noted that a one-percent increase in per capita income results in a 2% reduction in the threat to endemic mammal species. Similarly, this increase reduces the threat to endemic bird species by 0.93%. The result is intuitive. Poverty justifies addressing the problems at the base of Maslow's pyramid. And the poorer a country is, the more it

will take care of its environment as a form of self-fulfilment. For Sol (2018), richer countries and regions can generate enough resources to maintain their wildlife wealth.

The first demography variable, population density ($\ln pop$), has a negative sign. Increasing it by one percent causes a decrease in biodiversity loss, according to estimates. Specifically, in the endemic models, an increase in the population growth rate causes a 2% increase in the extinction risk of mammalian species. However, it reduces the threat to birds by 3.2%.

This relationship is more consistent in non-endemic models. In this case, a one-percent increase in population growth rate will reduce the threat to mammals by 0.31% and the risk of extinction for the bird population by 0.19%.

The explanation given is the intrinsic composition of population growth. The threat to mammal and bird populations will tend to increase if rural population pressure dominates population growth. If, on the other hand, population pressure is greater in urban areas, there will be a reduction in the threat to endangered species.

Variable population density has a direct relationship with biodiversity loss. An increase in population density increases the risk of extinction of bird populations in the endemic model by 0.03% (column 2). The same increase in the number of people per square kilometre tends to increase the extinction of species in mammal and bird populations by 0.004% and 0.003%, respectively.

Countries with low population density exert less pressure on threatened animal populations. On the other hand, countries with high population density contribute to increasing pressure on threatened species. This is explained by the strong competition for food and subsistence that characterises high-density countries, all other things being equal. This relationship is consistent with the results observed in the literature. Indeed, Ullah and Kim (2021) find that human activity, captured by demographic variables, is positively related to proxies of biodiversity loss.

The analysis of our institutional variables allows us to establish and confirm two theoretical intuitions. When governance is captured by the composite index of all governance indicators, the variable (Gov) in all the models captures the beneficial effect on biodiversity loss. On the other hand, when the improvement in the quality of institutions by a single indicator is captured, the effect is perverse on the loss of biodiversity.

First, there is a negative relationship between overall governance improvement and biodiversity loss. Thus, when the overall index of institutional quality increases by one unit, it reduces the loss of endemic and non-endemic mammal species by 2.4% and 0.85%, respectively. These results are

significant at the 1% level. Similarly, increasing the composite index by one unit reduces the loss of bird species in the non-endemic model by 0.26%. This result is statistically significant at the 5% level.

Secondly, there is a positive and significant relationship between the improvement of an isolated indicator of institutional quality and the reduction of biodiversity. With a significance of 1%, the improvement of one unit of the rule of law variable increases the loss of endemic mammal species by 9.3%. Similarly, it exacerbates the loss of non-endemic species by 2.53% and 0.9% for mammals and birds, respectively. These results are all significant at the 1% level.

The two relationships identified are expected relationships. According to the literature (Iritié, 2015), improving governance globally and improving an isolated indicator have different impacts on biodiversity loss. When the state strives to build better institutions across the board, biodiversity conservation is more guaranteed. On the other hand, when a single indicator is taken into account, all other things being equal, it accentuates the deviations of human activity and increases the risk of the extinction of threatened species.

In addition, there is little criminalization of the illegal hunting of protected species. The strengthening of the law can have negative effects on biodiversity conservation. For example, studying the deterrent effect of penalties in Africa, Challender and MacMillan (2014) argued that while intensifying enforcement efforts was necessary, it was not sufficient to protect the most highly valued species. Rising prices of animal products and deepening poverty in areas of supply had both increased the incentive to hunt illegally. The study suggested that the only solution to the problem was to address poverty in the supply areas, building both the incentives and the capacity within local communities to conserve wildlife (Perrings and Kinzig, 2021).

The increase in protected areas (PA) has a positive relationship with the threat to endemic mammal species. At the 1% threshold, a one percentage point increase in the protected area increases the loss of endemic mammal species by 0.04%. However, increasing protected areas by one percentage point reduces the loss of endemic bird species by 0.03%. It also reduces the losses of non-endemic bird species by 0.004%. The coefficients are significant at the 1% level.

A possible explanation for this result is the lack of inclusion of local communities in the management of protected areas. For communities, mammals are financially important (Ullah and Kim, 2021). The establishment of protected areas that do not involve communities is dangerous for endemic mammal species. This is because protected areas are not a deterrent to the community's efforts to ensure the protection of endemic mammal species. This result for mammals is in contrast to that found by Ullah and Kim (2021) and is similar for birds.

The coefficient of the binary variable 'landlocked' introduced in the models captures the effects of being landlocked on biodiversity loss in Sub-Saharan Africa. It is found that being landlocked reduces the threat to bird species (endemic and non-endemic) and non-endemic mammal species. These coefficients are all significant at the 1% level. Such a result can certainly be explained by the fact that landlocked countries are slightly more difficult to access (by land or sea) than non-landlocked countries. They are therefore less attractive to hunters and traffickers of biodiversity.

The results obtained in this subsection highlight that there is a direct relationship between the expansion of agricultural land and biodiversity loss. Agricultural expansion is measured in terms of the ratio of arable land to the total area of the country, or the area of land allocated to cereal crops. The estimation technique used is the pooled population-averaged technique used for short panels. In the following subsection, the robustness of the relationship is analysed by varying the estimation technique.

5.3.2. Using an alternative estimation technique

The estimated coefficients of the relationships between the variables of interest using the methodology for long panels are hosted in table 21 page 161. In general, it is found that the variables have coefficients of the same statistical sign and significance as those obtained in the basic model of the previous subsection.

The relationship between the agricultural land expansion variable and the estimated biodiversity loss variable shows that agricultural expansion increases the risk of extinction for threatened species. The effect is more significant for endemic species and less so for non-endemic species.

The variables agricultural intensification (agvapw) and protected areas show signs consistent with the results obtained in the baseline model. Overall, they significantly reduced biodiversity loss in sub-Saharan Africa. The same is true for the proxies of institutional quality.

These estimates are robust to the presence of panel heteroscedasticity and the presence of a serial correlation of order one (1), which could potentially bias the results. The estimated Chi2 coefficients are significant at the 1% level. This means that the model is globally significant, as the variables taken together are different from zero.

After having analysed and validated the robustness of the agricultural expansion relationship and obtained the Feasible General Least Squares (FGLS) estimates, the robustness of the relationship using an alternative specification of the model is assessed.

Table 21: Agricultural land and biodiversity loss, robustness check

Dependent variables	(1)	(2)	(3)	(4)
	Endemic Mammals	Endemic birds	Non Endemic Mammals	Non Endemic Birds
Agricultural land	0.0362** (0.0151)	0.0155*** (0.00441)	-0.00603** (0.00247)	0.000567 (0.00149)
Cereal land (log)	0.709*** (0.224)	-1.131*** (0.0503)	0.191*** (0.0138)	-0.256*** (0.0152)
Intensive ag.	-0.000281* (0.000158)	-0.000555*** (5.97e-05)	-0.000173*** (3.26e-05)	-0.000167*** (1.63e-05)
Gdp per cap (log)	-1.623*** (0.511)	-0.942*** (0.133)	0.233*** (0.0650)	0.119*** (0.0335)
Population density	-0.0244*** (0.00652)	0.0381*** (0.00259)	0.00416*** (0.000456)	0.00164*** (0.000595)
Pop. growth (log)	1.931*** (0.708)	-3.465*** (0.262)	-0.288*** (0.0447)	-0.112** (0.0538)
Governance	-1.987*** (0.326)	0.412* (0.226)	-0.368*** (0.0543)	-0.142*** (0.0195)
Rule of law	7.561*** (1.108)	0.480 (0.592)	0.925*** (0.148)	0.636*** (0.0339)
Protected areas	-0.0232** (0.0102)	-0.0355*** (0.00286)	-0.00379** (0.00159)	-0.00648*** (0.000931)
Trade			-0.00851*** (0.00101)	-0.00132** (0.000626)
1.landlocked (1 if yes, 0 if no)	-0.262 (0.467)	-2.181*** (0.164)	-0.943*** (0.0709)	-0.543*** (0.0685)
Constant	30.54*** (6.194)	2.969 (2.392)	3.433*** (0.626)	0.837** (0.389)
chi2	203.3***	965.4***	618.9***	1691***
Observations	36	35	93	93
Number of id	12	12	31	31
Panel Correlation	Heteroskedastik	Heteroskedastic	Heteroskedastic	Heteroskedastic
Serial Correlation	AR1	AR1	AR1	PSAR1

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author

5.3.3. Using alternative model specification and measures of agricultural land expansion.

The robustness of the relationship between agricultural expansion and biodiversity loss is analysed using another specification, and an alternative proxy for extensive agricultural growth is presented in table 22.

The new variables of interest are arable land and permanent land. It has been found that expansion accelerates biodiversity loss. It is found that an increase in permanent land has a significant impact on the increase in biodiversity loss for birds in general as well as for endemic bird and mammal species. These effects are significant at the 1% level. This result closely matches that of Ahrends et al. (2017), who show that the expansion of latex monoculture has a destructive effect on biodiversity

as it promotes the destruction of several animal and plant species in favour of one particular speculation.

Table 22: Agricultural expansion and biodiversity loss, alternative measure of land expansion

Dependent variables	(1)	(2)	(3)	(4)
	Mammals Endemic	Birds Endemic	Mammals Non Endemic	Birds Non Endemic
Arable land	0.561*** (0.108)	0.480 (0.592)	0.925*** (0.148)	0.636*** (0.0339)
Permanent land	0.886*** (0.194)	0.768*** (0.104)	0.185*** (0.0433)	0.211*** (0.0323)
Intensive agriculture	0.00291 (0.000219)	-0.000780*** (0.000145)	-0.000114*** (4.40e-05)	-0.000296*** (3.21e-05)
GDP per cap (log)	-3.516*** (0.515)	-0.508** (0.223)	-0.0915 (0.0747)	0.175*** (0.0296)
Population density	-0.0106*** (0.00343)	0.0190*** (0.00290)	0.000325 (0.000769)	0.000785* (0.000443)
Pop. growth (log)	-0.297 (0.517)	-1.847*** (0.319)	-0.100 (0.0697)	-0.0276 (0.0450)
Governance	-0.846** (0.382)	0.572*** (0.101)	-0.0117 (0.0597)	-0.185*** (0.0285)
Rule of law	4.563*** (0.944)	-0.424* (0.217)	0.159 (0.159)	0.615*** (0.0735)
Protected areas	-0.0249*** (0.00725)	-0.0219*** (0.00305)	-0.00136 (0.00160)	-0.00345*** (0.000984)
Trade	-0.0442*** (0.00871)	-0.00653* (0.00370)	-0.00663*** (0.00156)	-0.00251*** (0.000638)
Landlocked countries (1 if yes, 0 if no)	-0.240 (0.296)	-1.772*** (0.251)	-0.779*** (0.0998)	-0.697*** (0.0745)
Constant	35.80*** (4.711)	10.34*** (2.422)	4.905*** (0.706)	4.044*** (0.325)
Chi2	494.6***	802.9***	209.6***	644.0***
Number of id	12	12	31	31
Observations	36	35	93	93
Panel Correlation	Heteroskedastic	Heteroskedastic	Heteroskedastic	Heteroskedastic
Serial Correlation	AR1	PSAR1	AR1	AR1

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Author

Looking at the signs and significance of other coefficients, one notes that the relationships are for the most part consistent with those obtained in the baseline specification. The significance of the Chi2, taking into account the possible heteroscedasticity of the panel as well as the risk of serial correlation, makes it possible to attest to the quality of the adjustments produced and summarised in this table.

6. Conclusion

It is known that the majority of sub-Saharan countries have an abundance of land and have good reasons for seeking to expand their agricultural areas. Tropical forest ecosystems, which are the most species-rich environments, are being reduced rapidly because of agricultural land expansion (FAO, 2019), threatening therefore environmental dimension of agricultural sustainability. The trend of rapid agricultural land expansion in African tropical regions is of major concern to the problem of biodiversity loss because of the implications for the conversion of many species' natural habits.

Several studies have identified diverse sources of biodiversity loss, among which are population increase and economic growth (Sol, 2019), agricultural land expansion (Molotoks et al., 2020; Perrings and Halkos, 2015), institutional quality (’t Sas-Rolfes, 2017; Muchapondwa and Stage, 2015), and community protected areas (Ullah and Kim, 2021). Most of these use country-level methodologies or imagery observation. No previous study has neither used non-endemic species to test the relationship between land expansion and biodiversity nor used a short panel analysis, which provides more information than a country-level study. The aim is to fill this gap.

This essay examines the effects of agricultural land expansion on both endemic and non-endemic species of mammals and birds from 2013 to 2015 due to the availability of data. A set of 31 countries is included in the analysis. A Population-Average (PA) approach also known as Feasible General Least Square (FGLS) is used as an estimation technique to determine the parameters of the baseline equation. To evaluate the robustness of relationships, the approach adopted accounts for heteroskedasticity and serial correlation.

The main result of this essay suggests that agricultural land expansion is a significant factor accelerating biodiversity loss in sub-Saharan African countries. Independent of the taxonomy (mammals or birds) and irrespective of the model (endemic or non-endemic), using more land for agriculture purposes increases threats to biodiversity. This finding converges with previous studies (Perrings and Halkos, 2015; Sol, 2019; Ullah and Kim, 2021). The latter provide evidence that extensive agricultural growth is a key driver of species extinction. The most probable reason is that agriculture depletes the natural habitats of animals and places them in unsafe places.

Moreover, improving all the indicators of governance is more worthwhile for biodiversity conservation than making improvements to only one indicator—the rule of law in this case. Improvements in living standards reduce threats to biodiversity (Sol, 2019). Finally, creating or expanding protected areas is an efficient tool to reduce biodiversity loss in sub-Saharan Africa, according to Ullah and Kim (2021). All the relations are robust to other estimation techniques, model specification, and both heteroscedasticity and serial correlation. It is recommended to create farms with rich expansion and the use of organic farming methods.

GENERAL CONCLUSION

The main objective of this thesis is to analyse the effects of agricultural land expansion on agricultural sustainability in sub-Saharan African countries. A threefold decomposition of this main objective is unfolded in three essays. In the first essay, the objective is to inquire into the effects of agricultural land expansion on food security. The second essay's objective is to analyse the effects of agricultural land expansion on the type of structural change. The third essay seeks to investigate the effects of agricultural expansion on biodiversity loss in sub-Saharan Africa.

Globally, the study covers the period 1990–2016 in 41 sub-Saharan African countries. However, the specific time coverage for the essays varies with respect to the availability of data. Hence, essay one covers the period 2001–2016, while essays 2 and 3 cover the periods 1990–2016 and 2013–2015, respectively. In addition, the methodologies used to evaluate the effects of agricultural land expansion on agricultural sustainability vary according to the objectives and the available data. Precisely, in essay number one, Panel Random effects (RE) for the baseline results are used, and the robustness of relationships is assessed with the Generalised Moment Method in Difference (D-GMM) and in System (S-GMM). The second essay uses a Pooled Multinomial Logit Model (POMLOGIT) and checks robustness with both Random Effects Multinomial Logit Model (REMLOGIT) and the Effects Multinomial Logit (FEMLOGIT). Finally, the third essay employs a Pooled Feasible Generalised Least Square (PFGLS) model for short panels to derive the parameters of the baseline model. The same methodology, but for long panels, helps check the robustness. The main results obtained are presented as follows:

- **Main results**

The expansion of agricultural land through increasing returns of scale leads to an increase in production, resulting in agricultural surplus and income. This surplus decreases the price of agricultural products and improves access to food in terms of both quantity and quality. Consequently, the prevalence of undernourishment is reduced. Moreover, the increase in production leads to a crowding-out effect, contributing to the release of labour from the agricultural sector to other sectors such as the processing of the agricultural surplus. As a result, an increase in investment by firms is observed, leading to the creation of new job opportunities. Additionally, the released producers from the agricultural sector are motivated to diversify their activities in the secondary sector, which ultimately leads to an increase in the likelihood of observing a more industrialised economic structure.

The summary of the results is presented in three subsections. First, the effects of land expansion for agriculture on food security, then the type of structural change, and lastly, the biodiversity change.

- **Effects of agricultural land expansion on food security**

The key findings of this essay suggest that the expansion of arable land available for agriculture reduces the proportion of undernourished people. The reason provided here is based on the assumption of increasing returns to scale. Primary arable land is generally more fertile than secondary land. The latter will require more inputs to carry out the agricultural activity and can generate a higher proportion of production. This agricultural product will help boost food availability and therefore reduce the proportion of undernourished people while holding other factors constant.

- **Effects of agricultural land expansion on the type of structural change**

The results show that the increase in agricultural land not only causes structural transformation but also increases the probability of countries having an industrial structure rather than a service structure. An increase in land for cultivation causes a rise in productivity, which not only releases a surplus of production but also releases the surplus labour in the agricultural sector, which causes a structural change. This creates more incentives for processing the additional agricultural yields and increases the likelihood of observing a more industrialised economic structure. Overall, this essay shows that land expansion for agriculture creates a ‘virtuous’ structural change. The more sub-Saharan countries use the land available for agriculture, the more likely they are to industrialise their economic structures.

- **Effects of agricultural land increases on biodiversity change**

The main result here suggests that agricultural land expansion is a significant factor accelerating biodiversity loss in sub-Saharan African countries. Independently from the taxonomy (mammals or birds) and irrespectively of the model (endemic or non-endemic), converting more land for agriculture purposes increases threats to biodiversity and the risk of extinction. This confirms the common belief and precedent findings that extensive agricultural growth is a key driver of species extinction.

Ultimately, the expansion of agricultural land can play a crucial role in improving access to food for local populations and promoting structural change. However, it is important that this expansion be managed sustainably and environmentally respectfully in order to minimise negative impacts on local ecosystems and ensure long-term food security and sustainable structural transformation.

- **Recommendations**

Civil society organisations, non-governmental organisations and policy makers should promote the creation of more protected areas that will both enhance biodiversity conservation and food and nutrition security.

Also, policy makers, international donors organisation and civil society organisations should increase investments efforts to expand the size of planted forests since the latter provides ecosystems services and socioeconomic gains.

Moreover, extension services, producers organisations, civil society organisations and policy makers should promote the adoption of agroforestry practices which can be incorporated in agricultural land expansion in order to provide socioeconomic and environmental services. Given that agroforestry will provide habitats for threatened species, raw materials needed for industrial type of structural change and at the same time provide food need to alleviate undernourishment. Investing efficiently in that sub-sector will help to reduce threats to natural habitats while increasing the productivity of agricultural output per unit of land and per agricultural worker (Giller, Delaune, et al., 2021; Giller, Hijbeek, et al., 2021; Pawlak and Kołodziejczak, 2020).

- **First essay recommendation**

States should improve the land tenure system and the functioning of land markets. It is necessary for African states to halt the acquisition of agricultural land and its exploitation by foreign firms. The acquisition of arable land by either foreign nationals or local populations is of undeniable importance for the food security of African countries. The gains that foreign countries, as secondary holders of land, are making only benefit themselves.

It is suggested that sub-Saharan states review and strengthen legislation around the retention of food production within the national territory and even impose the processing of a portion of the output produced locally. This will make it possible to retain, within national borders, agro-food products that are important for the fight against undernourishment.

The need for more intensive and diverse land use based on the domestication of indigenous trees to produce high-value products while increasing agroecosystem resilience Approaches that include these three issues will transform smallholder farming in Africa into productive and sustainable enterprises and will greatly contribute to food security and environmental conservation, creating a win-win situation.

Expanding aquaculture and promoting organic agriculture (Schoonbeck et al., 2013), which prevents land degradation and even improves soil fertility (Kaihura et al., 1999; Niggli et al., 2007).

- **Second essay recommendations**

Land policies and investments should focus on improving the productivity of smallholder agriculture. This requires a more equitable distribution of land and means of subsistence in remote and land-abundant regions. By way of illustration, it has been proven that in specific areas, research results, their dissemination, access to markets, improvement of health and education services, and agricultural development improve livelihoods for the poor, increase employment opportunities, and even reduce environmental degradation. Thus, such targeted investment policies, consistent with the needs of small rural farmers, must be multiplied even in various parts of the remotest developing countries. The expected effect is that they would, in addition to reducing poverty and income inequality, spread more widely the economic and social gains that may occur as border areas develop.

The States must set up agricultural land expansion programmes or intervention mechanisms on land markets favourable to communitarianisation, the securing of agricultural land, and the improvement of land tenure. They should generate some programmes to clear excessive farm fragmentation and manage it efficiently, as they did for the community forest. Hurdles posed by excessive fragmentation of landholdings need to be overcome. About 85 percent of Africa's farmers are smallholders with cultivation areas of less than 2 hectares. They are too small to be economically viable.

The state must increase the dissemination of agricultural research products. This is the case with mechanisation and the use of improved seeds, which are necessary to obtain economies of scale. Continue to support agricultural mechanisation, which is a solid support for agricultural expansion and a bridge to industrialization.

In addition, policies and investments should aim to improve small-scale agriculture, land distribution, and livelihoods in remote and land-rich areas and better support those who switch to more commercial agriculture..

- **Third essay recommendations**

African countries should promote agricultural intensification through the deployment of greenhouses and organic farming. Indeed, such practises have the double advantage of increasing yields fourfold and respecting endangered species. Expanding aquaculture and promoting organic agriculture (Schoonbeck et al., 2013), which prevents land degradation and even improves soil fertility (Kaihura et al., 1999; Niggli et al., 2007). It will be possible to solve the problems of food security, structural

transformation patterns, and respect for biodiversity. Similar processes are already being implemented on the outskirts of Douala, Cameroon.

Creating and expanding new community protected areas to favour conservation of endangered animal species The management board of the protected areas should include the local population. This will reduce the risk of illegal hunting (poaching), which greatly increases the risk of the extinction of taxonomic groups.

Design context-specific law enforcement to fight against biodiversity loss. Localities where poverty is increasing and biodiversity is rich tend to defy established laws as the price of animals increases.

More importance should be given to the fight against poverty to encourage respect for biodiversity, especially in species-rich areas..

- **Limitations of the study**

This study suffers from methodological, empirical, and policy recommendation limits.

In general, our policy recommendations are not country-specific. Actually, the conclusions and policy recommendations we formulate require a regional-level policy and do not account for the specificities of each country. As a matter of fact, there are some important differences in the agricultural land expansion patterns within African countries. Consequently, it is important to extend this study at the country level to get further insights on the impact of these policies.

In the second essay, despite the robustness of the results, there is no way to test the goodness of fit of the model for the estimation of the random effects model (REMLOGIT) or for the fixed effect model (FEMLOGIT). On the other hand, the results clearly show that the increase in agricultural land created a movement of labour into the industrial sector. However, the study does not sufficiently identify the reasons why the structural change of landlocked countries differs from that of sea-opening countries. Further research needs to be done in this direction.

In the third essay, the main limitation is the availability of data. Although the study used an adequate methodology for a short panel analysis, he could have the strongest relationships with panel data from 1990 for all sub-Saharan African countries. However, panel data are very difficult to access from the IUCN. Relevant series are difficult to find, and we are still waiting for the IUCN to provide us with data..

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Annexes

Annex 1: Models of sustainability

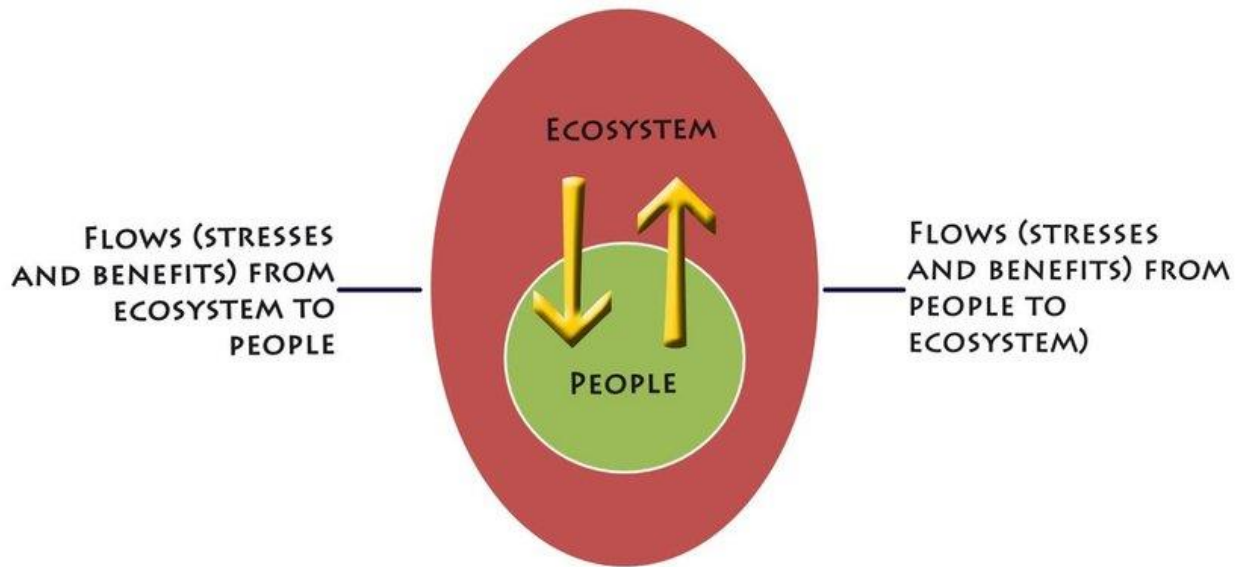


Figure 27: The egg of sustainability

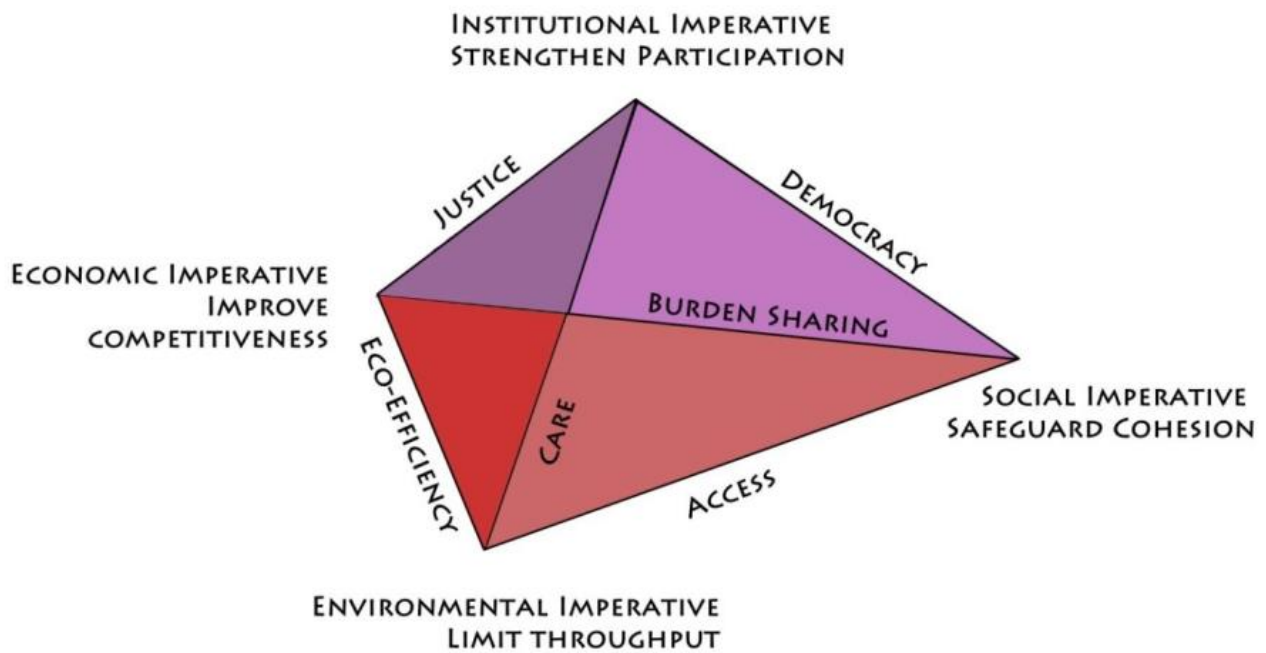


Figure 28: The prism of sustainability

Annex 2 : Countries in the study

Essay 1

Opened countries

Angola, Benin, Cameroon, Congo, Rep., Gabon, Gambia, The, Ghana, Kenya, Liberia, Madagascar, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, Togo

Landlocked

Botswana, Burkina Faso, Chad, Ethiopia, Lesotho, Malawi, Malawi, Mali, Rwanda

Essay 2

Opened countries

Angola, Benin, Cameroon, Comoros, Congo, Dem. Rep., Congo, Rep., Equatorial Guinea, Eritrea, Gabon, Gambia, The, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo

Landlocked

Botswana, Burkina Faso, Burundi, Central African Republic, Chad, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Uganda, Zambia, Zimbabwe.

Essay 3

Opened countries

Angola, Benin, Cameroon, Comoros, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Tanzania, Togo

Landlocked

Botswana, Burundi, Chad, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Uganda, Zambia, Zimbabwe

Annex 3: Variables used in the study

Table 23: Full description of variables

Names	Labels	Source
<i>aland</i>	Agricultural land	
<i>undnrsh</i>	Prevalence of undernourishment	
<i>tsc*</i>	Type of structural change (Inspired by Baymul and Sen, 2020)	
<i>pi*</i>	Production Index (Based on Tankeu, 2020; Kinda and Badolo, 2019)	
<i>lnco2</i>	CO2 emissions (kt)	
<i>lngdpcap</i>	Gross domestic product per capita, constant (in log)	
<i>fpv*</i>	Food Price vulnerability index (Based on Kinda and Badolo, 2019; Combes et al., 2014)	
<i>popg</i>	Population growth	
<i>rurpop</i>	Rural population (% of total population)	
<i>popdens</i>	Population density (people per sq. km of land area)	
<i>indspill*</i>	Spillover from agriculture to industry (Inspired by Baymul and Sen, 2020)	
<i>scespill*</i>	Spillover from agriculture to service (Inspired by Baymul and Sen, 2020)	
<i>tb</i>	Incidence of tuberculosis (per 100,000 people)	World Development indicators (WDI, 2020)
<i>phiv</i>	Prevalence of HIV, total (% of population ages 15-49)	
<i>arlandcap</i>	Agricultural land per capita	
<i>arable land</i>	Arable land (% of land area)	
<i>cland*</i>	Land under cereal production (% of land area)	
<i>for</i>	Forest area (% of land area)	
<i>pland</i>	Permanent cropland (% of land area)	
<i>trade</i>	Trade (% of GDP)	
<i>minerent</i>	Mineral rents (% of GDP)	
<i>Water total</i>	Improved water source (% of population with access)	
<i>Sanitation total</i>	Improved sanitation facilities (% of population with access)	
<i>Water rural</i>	water source, rural (% of rural population with access)	
<i>Water urban</i>	water source, urban (% of urban population with access)	
<i>Sanitation urban</i>	sanitation facilities, urban (% of urban population with access)	
<i>Sanitation rural</i>	sanitation facilities, rural (% of rural population with access)	
<i>gov*</i>	Governance index (Inspired by Totouom et al, 2019)	World Government Indicator (WGI, 2020)
<i>rle</i>	Rule of law	
<i>mmt</i>	Total Mammals species	International Union for Conservation of Nature (IUCN, 2020)
<i>mame</i>	Mammals endemic species	
<i>bt</i>	Total Birds species	
<i>be</i>	Birds endemic species	
<i>pa</i>	Terrestrial protected areas (% of total land area)	World Database on Protected Areas (WDPA)

*Variables constructed by the author

Annex 4: Supplementary Outcomes

Table 24: Principal components/correlation : governance index

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	4.78629	4.30563	0.7977	0.7977
Factor2	0.48067	0.13806	0.0801	0.8778
Factor3	0.34261	0.12274	0.0571	0.9349
Factor4	0.21987	0.11782	0.0366	0.9716
Factor5	0.10205	0.03354	0.0170	0.9886
Factor6	0.06851	.	0.0114	1.0000

Table 25: Principal component/correlation : production index

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.50833	.580478	0.5028	0.5028
Comp2	.927854	.364041	0.3093	0.8121
Comp3	.563813	.	0.1879	1.0000

Table 26: Summary statistics essay 2

Sea coast Countries					
	count	mean	sd	min	Max
aland	726	45.93724	20.7589	3.26087	80.92054
arlandcap	726	.2204696	.1057377	.0015439	.5563928
gdpcap	712	2618.945	3491.326	200.6313	20532.95
popg	697	.0257495	.0099637	-.0262866	.0790219
gov	486	5.375858	1.825777	1.063459	9.931457
pland	726	3.042974	5.295959	.0024293	29.554
trade	682	72.65652	37.56172	20.72252	311.3541
Landlocked countries					
aland	375	45.76765	19.68747	8.035571	82.67134
arlandcap	378	.3302578	.2644735	.0970429	1.515974
gdpcap	378	990.6976	1385.68	164.3366	7864.251
popg	364	.0243965	.0135885	-.0676622	.0811793
gov	252	5.380397	1.729467	2.347067	10
pland	375	2.77394	4.839821	.0017645	15.57632
trade	336	56.18993	26.25733	19.68416	161.8937

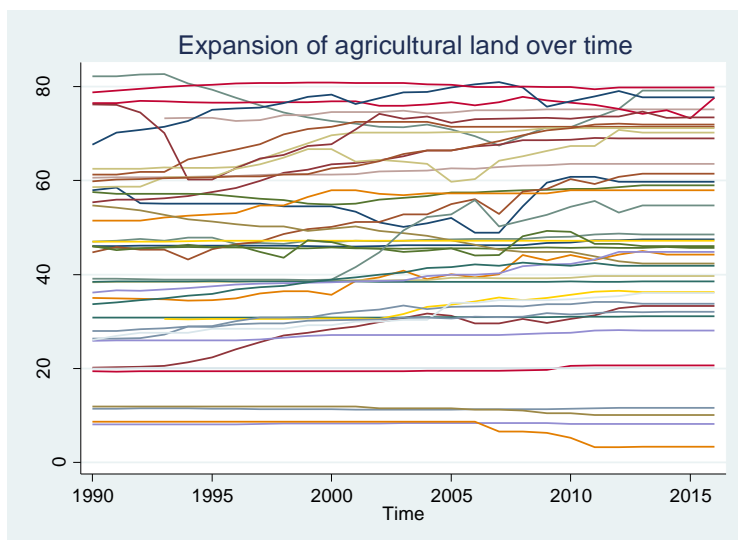


Figure 29: Evolution of agricultural land in Africa countries

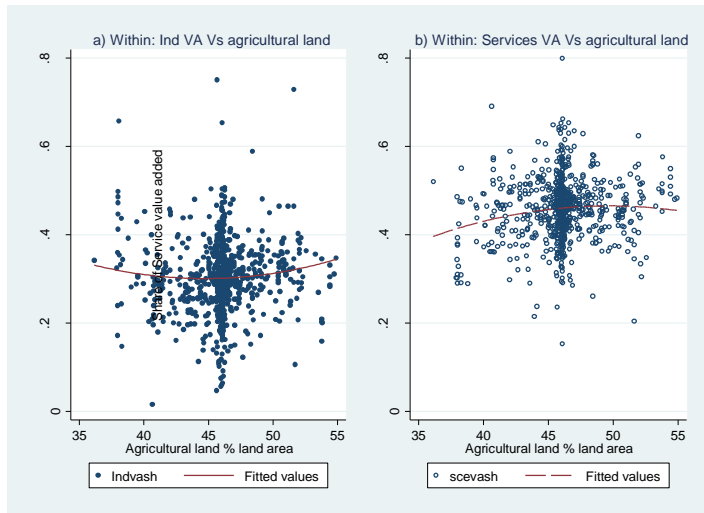


Figure 30: Agricultural land and sectoral value added

Supplementary estimation results

Table 27: Agricultural land and type of structural change - POMLOGIT

VARIABLE	pm1		pm2		pm3		pm4		pm5	
	Structurall y Developin g	Structurall y Developed	Structurall y Developin g	Structurall y Developed	Structurall y Developin g	Structurall y Developed	Structurall y Developin g	Structurall y Developed	Structurall y Developin g	Structurall y Developed
aland	1.027* (0.0153)	1.178*** (0.0613)	1.050** (0.0232)	1.180** (0.0907)	1.077*** (0.0260)	1.282*** (0.0901)	1.089*** (0.0294)	1.312*** (0.0931)	1.088*** (0.0292)	1.319*** (0.0741)
arlandcap	1.939 (2.471)	0.000766 (0.00461)	3.314 (11.45)	0.968 (4.774)	2.167 (7.727)	8.109 (20.62)	0.360 (1.710)	8.999 (26.26)	0.320 (1.589)	15.09 (37.45)
agIXva	1.000 (0.000415)	0.996*** (0.00133)	0.999 (0.000545)	0.994** (0.00242)	0.998** (0.000854)	0.990*** (0.00248)	0.999 (0.000774)	0.988*** (0.00375)	0.999 (0.000796)	0.988*** (0.00300)
lngdpcap	3.797*** (1.716)	11.94*** (9.658)	3.160** (1.459)	0.120 (0.174)	4.508*** (2.147)	0.0737** (0.0947)	9.303*** (4.723)	0.0677 (0.111)	9.120*** (4.676)	0.0373*** (0.0342)
l.landl	0.527 (0.303)	0.804 (0.832)	0.226* (0.184)	0.0968 (0.275)	0.216* (0.176)	0.167 (0.381)	0.306 (0.254)	0.279 (0.637)	0.312 (0.262)	0.203 (0.340)
popg			3.73e-08 (1.39e-06)	0** (0)	0 (0)	0*** (0)	0* (0)	0*** (0)	0* (0)	0*** (0)
gov			1.698*** (0.342)	8.633* (10.28)	1.632** (0.316)	13.61** (16.83)	1.766*** (0.357)	14.67** (16.47)	1.761*** (0.351)	19.07*** (12.90)
trade			1.008 (0.0116)	0.996 (0.0315)	1.006 (0.0109)	0.999 (0.0178)	1.005 (0.0110)	1.001 (0.0185)	1.005 (0.0109)	1.003 (0.0150)
popgXagva					8.974** (9.790)	36,610*** (93,379)	9.924** (10.88)	94,406*** (270,770)	9.808** (10.77)	200,245** (421,223)
pland							0.771** (0.0830)	1.026 (0.199)	0.772** (0.0820)	0.989 (0.294)
minerent								0.986 (0.0604)	1.155 (0.444)	
Constant	8.37e-06*** (3.07e-05)	0*** (0)	6.48e-07*** (3.44e-06)	0.315 (2.638)	6.02e-08*** (3.20e-07)	0.0506 (0.398)	1.95e-10*** (1.16e-09)	0.0801 (0.641)	2.54e-10*** (1.55e-09)	1.144 (9.953)
Observations	1,034	1,034	690	690	690	690	690	690	690	690
r2_p	0.416	0.416	0.530	0.530	0.548	0.548	0.577	0.577	0.578	0.578
N_clust	41	41	41	41	41	41	41	41	41	41
chi2	111.8	111.8	557.2	557.2	563.5	563.5	674.0	674.0	1523	1523

Robust seeform in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source : author

Scientific outcome 1

De : Ivonne Stephanie Lara Cortes
Envoyé le : mercredi 26 avril 2023 16:14
À : saubyphd@gmail.com
Cc : McNamara Fellowships program
Objet : RSMFP application results

Dear Saubaber Longang Gamo,

Congratulations! You have been longlisted for the **Robert S McNamara Fellowship Program**. You are being considered for a fellowship with the following team(s): **DIME - Agriculture and DIME - Finance and Private Sector**

The next step in the selection process is for you to complete a statistical software assignment for: **R, Stata or Python (let candidate choose which one)**

The deadline for completion is Tuesday, May 2nd, 2023, at 1:00 pm Eastern Time.

We kindly ask you to read the following [Pre-Test Instructions](#) before beginning the assignment. When you are ready to start your assignment, please visit the following [link](#).

Cordially,
Robert S. McNamara Fellowships Program Secretariat

Scientific outcomes 2



Ministère de l'Éducation
UNIVERSITE des SCIENCES DE LA VIE
„ION IONESCU de la BRAD” de IAȘI
“Iasi University of Life Sciences”

USV 1842

Date 17.11.2022

N° de référence 20.168/17.11.2022

À l'attention de M. Master professionnel **LONGANG GAMO Saubaber**,
Doctorant auprès de l'Université de Dschang, Faculté de Sciences Economiques et de
Gestion

Ville et pays de l'université d'origine : Dschang, Cameroun

Intitulé du projet de recherche : *Trois essais sur les effets de l'expansion des terres en Afrique
subsaharienne*

ATTESTATION D'ACCUEIL

Votre dossier de pré-inscription pour une bourse doctorale « Eugen Ionescu » nous est bien
parvenu.

Suite à l'analyse de ce dossier, nous avons le plaisir de vous annoncer que vous êtes accepté
par notre université, au sein de l'École doctorale, Faculté de Horticulture, Laboratoire de
Protection des Plantes, sous la direction scientifique de M. le Professeur univ. dr. Mihai
TĂLMACIU, pour effectuer un stage de recherche qui se déroulera du 01 Mai au 31 Juillet
2023, pour une durée totale de 3 mois.

Il vous revient à présent de déposer votre dossier complet de candidature auprès de
l'Agence Universitaire de la Francophonie, en vue de la sélection finale.

Les frais relatifs à votre séjour (matériels et expériences en laboratoire, assurance-maladie,
logement, transport, éventuelles taxes pour l'obtention du permis de séjour etc.) ne sont pas
pris en charge par l'université.

En vous souhaitant une bonne réussite dans vos projets, nous vous prions d'agréer nos
salutations distinguées.

Responsable administratif,
Monsieur Prof. univ. dr. Gerard JIȚĂREANU
Recteur de l'Université,

Signature et cachet:

Responsable scientifique,
Monsieur Prof. univ. dr. Mihai TALMACIU
Tuteur de doctorat, Responsable de Laboratoire de de Protection des Plantes

Signature:

Scientific outcomes 3

ANNUAL CONFERENCE ON AFRICAN POLITICAL ECONOMY2, ACAPE2 & ANNUAL CONFERENCE ON REGIONAL INEGGRATION IN AFRICA12, ACRIA12.

THEME: POLICY OPTIONS FOR AFRICA'S SUSTAINABLE AND INCLUSIVE GROWTH AND DEVELOPMENT.

ORGANIZED BY THE AFRICAN POLITICAL ECONOMY ASSOCIATION (APEA), VIRTUALLY, OCTOBER 22-23, 2022.

PARTNERS:

West African Institute for Financial and Economic Management (WAIFEM)

West African Monetary Institute (WAMI)

West African Monetary Agency (WAMA)

Foundation for Economic Research and Training (FERT)

SPONSORS:



[IU Hamilton Lugar School of Global and International Studies](#)

SATURDAY, OCTOBER 22, 2022.

All Times are West Africa Time (UTC+1).

For instance, 2p.m Lagos (UTC+1) is 1 p.m. Dakar and 8 a.m. Atlanta.

2.00 p.m-3. 00p.m: Opening and Keynote Address

Opening Addresses:-

- Baba Musa, Director General, WAIFEM
- Director General, West African Monetary Institute, WAMI
- Akpan H. Ekpo, University of Uyo, Chairman, Foundation for Economic Research and Training (FERT)
- Oladele Omosogbon, Indiana University, President, APEA
-

Goodwill Messages: -

Director General, West African Monetary Agency, WAMA
Director, Country Economics Department, African Development Bank, AfDB
Director/CEO, African Economic Research Consortium, AERC

Keynote Address:

SESSION 1. GROWTH TRAJECTORY

3.05 pm-3.45 pm.

Presiding:

1.	POLICY STABILITY AND ECONOMIC GROWTH SUSTAINABILITY: EVIDENCE FROM WESTERN AND CENTRAL AFRICA ECONOMIES	Gbenga Peter Sanusi
2.	TOWARDS SUSTAINABLE GROWTH IN AFRICA: RE-ASSESSING THE DEBT-FRAGILITY-GROWTH NEXUS	Akpan H. Ekpo Obukohwo Oba Efayena

Discussants:

- (1). Nwokolo C. Ifeoma
 - (2). Etayibtalnam Koudjom
-

SESSION 2. AGRICULTURE

3.50 – 5.10

Presiding:

1.	STRUCTURAL CHANGE EFFECTS OF AGRICULTURAL LAND EXPANSION IN AFRICA	LONGANG GAMO Saubaber NINGAYE Paul TANKEU MELI Yollande
2.	FOOD INSECURITY, HEALTH RISK AND CLIMATE CHANGE IN AFRICA: AN ENTREATY FOR AMBITIOUS ACTION AND INCLUSIVE DEVELOPMENT?	Nwokolo C. Ifeoma
3.	CLIMATE CHANGE ADAPTATION AND MAIZE PRODUCTIVITY: A GENDER-BASED ANALYSIS	Etayibtalnam Koudjom
4.	ANALYSEDU CONSENTEMENT A PAYER DES CACAOCULTEURS IVOIRIENS POUR L'AGROFORESTERIE : UNE APPROCHE PAR L'ECONOMIE COMPORTEMENTALE	KUNIBOUO K. K. Angelo DJEZOU W. Beaudelaire

Discussants:

- (1). Gbenga P. Sanusi
 - (2). Iroume A. Bouebe
 - (3). Oluwatosin Adeniyi
 - (4). Hermann Hegueu Ndoya
-

SESSION 3. YOUTH AND EMPLOYMENT

Scientific outcomes 4

Gmail - Email of acceptance for application within the Coimbra Grou...

<https://mail.google.com/mail/u/0/?ik=a6ebe91c25&view=pt&search=...>



Sauby Longang <saubyphd@gmail.com>

Email of acceptance for application within the Coimbra Group Short Stay Scholarship Programme at University of Cologne

1 message

Johannes Mueller <J.Mueller@verw.uni-koeln.de>
À : Saubaber <saubyphd@gmail.com>

24 mars 2023 à 14:58

Dear applicant,

Thanks for your interest in applying for a Coimbra Group Short Stay Scholarship at the University of Cologne. This is to confirm that University of Cologne is offering a place in the field of your studies. Prof. Dr. Peter Dannenberg is looking forward to accept a young researcher at his/her institute within the scheme of this scholarship and will work with the selected applicant from this round of bidding during his or her stay.

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CERTIFICATE OF PRESENTATION

The Second Young Scholars conference on Structural Change and Industrial Policy in Africa was hosted by the DSI/NRF South African Research Chair in Industrial Development (SARCHI-ID) and the Young Scholars Initiative (YSI) on 21 and 22 June 2022. The conference was a virtual conference and covered a range of topics including: *Trade and Regional Trade, Political Economy and Industrialisation, Industrial Policy, Sectoral Dynamics and Structural Change, Industrial Development and Gender, 4IR and Digital Transformation, Structural Transformation, Global and Regional Value Chains, Technology and Upgrading.*

The conference opened with a keynote address from Dr Adeyemi Dipeolu (Special Advisor to the President for Economic Matters in the Office of the Vice-President of the Federal Republic of Nigeria) and closed with a panel discussion between Dr Rob Davies (former Minister of Trade and Industry, South Africa), Dr Aloysius Ordu (Brookings) and Professor Magda Shaheen (American University in Cairo). Senior international scholars acted as discussants, providing feedback on presented papers.

This certificate certifies attendance and presentation of a paper by

LONGANG GAMO SAUBABER, University of Dschang


DSI/NRF SARCHI Industrial Development
Prof Fiona Tregenna
24 June 2022



Young Scholars Initiative
Dr Richard Itaman
24 June 2022



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