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# A market infrastructure for environmental intangibles: the materiality and challenges of index insurance for agriculture in Senegal

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## ABSTRACT

In Senegal, various development pilot projects experimented with agricultural index insurance to make drought insurable. These interventions produced ‘rainfall deficit’ as an environmental problem suited for such market-based solutions. Investigating the materiality of this index insurance scheme, I explore the *environmental market infrastructure*, which produces risk conventions, articulates governance and market requirements, and fuels the promise of cheap, efficient, and automated environmental risk management in the Global South. I show that the production of such risk requires both a selective reduction of the physical reality of drought and the substantial reordering of material activities that organize many actors around rainfall deficit. Meteorological data produced by rain gauges placed in Senegalese fields were a central element in the initial infrastructure of index insurance. However, as reductionist technologies are often prone to failure, this index insurance scheme met many challenges. After documenting the design of this insurance scheme and the obstacles encountered, the paper depicts how actors in charge of its implementation made a shift in the insurance infrastructure from field rain gauges to remote sensing – in order to re-energize index insurance’s expectations.

## Introduction

Investigating the development of environmental intangibles as specific market-based solutions to environmental problems, this Special Issue calls for a closer look at the ways in which such artifacts are materialized, made transferable, commodified and traded. This paper’s contribution is to explore the development of an index insurance solution for climate risks in Senegal through the study of its *environmental market infrastructure*, understood as the socio-material network required to simultaneously build an environmental intangible as well as generate its market. An environmental market infrastructure articulates three main dimensions. It requires technologies in order to make environmental phenomena commensurable, scientific knowledge defining the impacts of environmental changes, and finally the features of the market-based solution proposed to mitigate such impacts. The elements of the environmental market infrastructure explored by this paper include meteorological monitoring technologies, indexes, agronomic modeling, financial literacy training programs, underwriting software, expertise in climatology, and the work of various employees commercializing insurance or maintaining rainfall data. This infrastructure is a central technology in the design of environmental markets, as well as in the definition of what

counts as the environment. Moreover, it is crucial to examine it to apprehend how climate risks are constructed as objects of knowledge and development interventions, as well as ‘a nature that capital can see’ (Robertson 2006, p. 367).

As with other environmental intangibles, such as carbon credits, biodiversity offsets, or ecosystem services, index insurance enables the internalization of externalities thanks to the production of new types of commodities that can be bought and sold and which materialize the value of environmentally positive behavior or the cost of environmental risks (Chiapello and Engels 2020 in this special issue). The production of these commodities requires abstractions ‘to escape from the messy physicality and uniqueness of the [field] itself’ (Robertson 2006, p. 373) in order to fit into the circulation of capital. In the case of index insurance in Senegal, ‘rainfall deficit’ is the abstraction (the insurable risk) for the broader phenomenon of drought. Such abstractions are based on various commensuration processes required, and sometimes fail to organize markets for environmental intangibles as various studies have shown (MacKenzie 2008, Huault and Rainelli-Weiss 2011, Cooper 2015, Dauguet 2015, Barral 2020 in this special issue). If these works grasp the role of the technologies involved in such processes, they mostly focus on the cognitive and organizational dimensions of commensuration related to the environmental objects under scrutiny. Research bridging Science and Technology Studies (STS) and the sociology of finance, however, has shown that the study of the socio-material infrastructure of markets (code, cables, antennas, software design, and server locations) is also crucial to understand the transformations of finance (Laumonier 2014, 2019, MacKenzie and Pablo Pardo-Guerra 2014). As Mackenzie and Pardo-Guerra suggest, the point is not to fuel a deterministic conception of technology in financial innovation, but to document the underestimated importance of the material equipment of markets, the labor it requires, the challenges it encounters, and make the circulation of expertise visible. Another contribution to this perspective is William Cronon’s (2009) famous depiction of the commodification of agricultural ‘futures’ by Chicago traders. Cronon investigates how the Chicago Board of Trade succeeded – although at great expense – in commodifying a version of grain independently of the crops themselves, thanks to various infrastructural changes both in the agricultural production system and in the conventions of trade (railroads, elevators, inspection and measurement procedures). Cronon analyses this shift as the production of a ‘second nature’ (the traded commodity) detached but articulated from a ‘first nature’ (the actual grain). Following Cronon’s analysis, this paper aims to identify how detachment and reordering are produced by agricultural index insurance to understand how environmental intangibles contribute to the contemporary transformations of capitalism and international development aid.

Sometimes, the environmental infrastructure precedes the market. This happened with weather forecast services, which were historically produced by public agencies. In most countries, the commodification of meteorological data was progressive, and supported the expansion of various market innovations developed afterward (Randalls 2010, 2017). In other settings, the environmental intangible requires new infrastructure to be built in order to create a market. This was the case with the construction of insurance markets for agriculture in the Global South when the insurance industry and development agencies faced the problem of the lack of robust data on historical events and losses. Index insurance came up as a ‘solution’ to this problem, providing a scheme that pays out for losses based on a predetermined index related to weather events (such as rainfall levels), without requiring the insurance company to assess the claim (the actual effects of drought in the field). As the index is a proxy for losses, the process is supposed to be automatized. Theoretically, the insurance contract is based on

climate-agronomic thresholds determining the prices of the premiums and the claims. During the crop season, environmental data is recorded through sensors (rain gauges or remote sensing via satellite technologies), and if the rainfall level is below the threshold in the area of the insured field, the claim is automatically paid to the policyholder. Tracing the implementation of this environmental market infrastructure in Senegal, I will focus specifically on the interface between geo-referenced rainfall data, agronomic modeling, and financial design. Yet, as we will see, the market for agricultural index insurance did not expand as its sponsors hoped it would. The environmental market infrastructure then faced a paradoxical juncture, specifically concerning meteorological sensors. Some rainfall data (produced through rain gauges) was blamed for these challenges, while other sources of rainfall data (produced through remote sensing) were seen as the source of new future opportunities for the market.

Exploring how an environmental danger is translated into an insurable risk and the challenges this translation face, the paper asks: What technologies are necessary to turn drought into the insurable risk of ‘rainfall deficit’? Moreover, how do market challenges impact this infrastructure? While answering these questions, the paper makes two claims. The first claim is that the environmental market infrastructure produces intangibles – the insurable ‘rainfall deficit’ – by selectively reducing the physical reality of drought and by formalizing an economic circuitry between recorded rainfall, agricultural practices and norms, modes of investments, and schemes of indebtedness in rural Senegal. This reordering is achieved by correlating meteorological data and agronomic modeling to produce and price the risk and embed index insurance into other financial technologies (development aid, microcredit). Index insurance requires a large machinery to construct its world (Cronon 2009, Robertson 2012) in order to turn agricultural producers into financial consumers (Johnson 2013). Second, the paper shows that if the infrastructure supports the promises of such emerging markets, it can likewise be blamed for the challenges faced. After an infrastructural investment was made by development agencies to build a market for environmental intangibles – by using rain gauges as the main source of environmental data – this infrastructure was blamed for market failure and then eventually replaced by satellite data as a new source of information.

The arguments in this article are arranged in four sections. In the first one, I describe how development agencies encouraged the use of index insurance to manage climate risks in Senegal and implemented the index insurance’s financial, legal, and material infrastructure. In the second section, I investigate the design of the index and the choice of a specific meteorological technology (rain gauges) to produce the data. I also focus on the work conducted in the field by climate-agronomists and insurance employees to design ‘rainfall deficit’ as a proper and transferable entity. This risk had to be purified and extracted from the physicality of the various fields where rain gauges are placed, and from the historical, organizational, and socio-material relationships that farmers have with their environment, among themselves, and with the many institutions structuring Senegalese’s agricultural economy. The abstraction of ‘rainfall deficit’ is correlated to the production of an alternative view of the world through risk, based on two main dimensions: agro-climatic modeling and risk zoning. In the third section, the paper looks beyond the promises of index insurance and documents various challenges met in its maintenance and its marketization. I will reflect on three kinds of problems that the environmental intangible creates or fails to make manageable: challenges in meteorological data production, challenges in the distribution scheme, and disputes between the domestic insurer and the global reinsurance industry about the underlying value of risks. The fourth and final section explores how rain gauges were made

responsible for some of these challenges. This blame contributed to an infrastructural shift towards remote sensing technologies (a trend of global dimensions), while in Senegal, new uses for rain gauges were envisaged as calibration tools for satellites or as data providers for future ‘climate services,’ yet to be developed.

This article is based on fieldwork conducted in Senegal in September and October 2017, specifically in Dakar and the Siné Saloum region. Twenty-five semi-direct interviews were conducted with program coordinators in international development agencies, scientists and experts, insurance directors and employees (meteorologists, actuaries, financial literacy trainers, sales directors), bankers, agricultural technicians, farmers’ representatives, and farmers. The technical and scientific literature on index insurance was collected and read, as well as reports from development agencies and the insurance industry.

## **International aid and market construction in Senegal**

Index insurance in Senegal finds its roots in various national and global environmental and socio-economic policies. Development agencies – the World Bank and the USAID in particular – had a central role in the making of such regulations and in the construction of the insurance infrastructure. In recent years, climate change adaptation has become an entry point for many international development programs (Taylor 2014, Viard-Crétat and Buffet 2017), to integrate Global South agricultural systems into new risk management schemes operated by the private sector. Index insurance for agriculture came up as one of these schemes in the early 2000s, promising to improve adaptation by insuring agricultural production against local weather variability, and better integrating small and environmentally vulnerable farmers into the global economy (World Bank Group 2018). For a critical analysis of this framing, see Johnson (2013).

As such, index insurance promises to contribute to climate change adaptation by redrawing the global boundaries of insurability beyond industrial countries and by covering environmental risks that were previously considered as non-insurable. Senegal is a good example of the challenges of such expansion, as it has a long history of climate risk exposure, rural indebtedness, a vulnerable agricultural labor force, and fragile state response schemes when crises strike (Bernards 2019). Senegal is not a welfare state, and insurance is not the technology of collective risk management there. Its population primarily lives in an informal economy, and so is not used to such financial services. Furthermore, no historical track record of the effects of drought on agriculture is available, so a statistical understanding of the losses suffered by farmers over time is not possible. These challenges partially explain why the private insurance industry is still reluctant to invest in these new markets, which are mostly funded today by public development agencies.

The emergence of index insurance converges with changes in the modes of governing rural development, particularly the withdrawal of structural adjustment policies in the 1980s and the 1990s, which caused significant damage in Senegal (Faye 2005, Bernards 2019). By the early 2000s, the failure of these neoliberal policies was commonly acknowledged, a shift enacted by the Law for Agro-Sylvo Pastoral Orientation that placed agriculture at the center of Senegal’s economic growth project and established the principles of a welfare regime for the social protection of farmers. On paper, this included health insurance coverage, but also an insurance scheme against natural disasters that was gradually implemented into an index insurance program. However, twenty years later, index insurance corresponds less like a state public welfare scheme and reinforces more the new trend of international development:

offering financial services designed to meet the needs of farmers captured as consumers with alleged calculative interest (Elyachar 2012). Public authorities are involved, in any case, as this framework led to the creation in 2008 of the Compagnie Nationale d'Assurance Agricole du Sénégal (CNAAS), the national agricultural insurance company. CNAAS does not operate alone and is assisted by a micro-insurance startup called Planet Guarantee, which is in charge of marketing, actuary work, and product and claim management – (I will use the term ‘insurance tandem’ for the partnership between CNAAS and Planet Guarantee). This tandem runs the index insurance program and struggles to operate effectively to satisfy the competing expectations of various actors (Johnson *et al.* 2018). Expectations are fueled, in particular, by development agencies that have targeted Senegal as an experimental site with various pilot projects,<sup>1</sup> aimed at capturing the diversity of the socio-economic and agronomic rural landscape. Together, they cover most of the country’s productive areas where agriculture is rain-fed: the tropical south and the central region where rainfall is the most variable. They insure most cereal crops and they target different types of farmers (seed producers, producers of grains for consumption or processed food, commercial farming, or subsistence agriculture). Among development agencies, the World Bank and the USAID have a leading role, which calls for further analysis.

The World Bank promotes the development of index insurance internationally through the Global Index Insurance Facility (GIIF). This program develops the index insurance scheme in Senegal, which required the setting up of the environmental market infrastructure. It started with the World Bank’s recommendation for creating CNAAS as a public-private partnership, owned by the Senegalese State (36%) and by African insurers and reinsurers from Senegal and Ivory Coast. The Bank also negotiated for the Senegalese government to subsidize farmers’ insurance subscriptions up to 50% of the premium,<sup>2</sup> as well as exempt them from VAT. In many countries, these two measures are traditional tools for governments to indirectly support the agricultural sector, and in Senegal, they lowered the prices of index insurance significantly to accelerate market development. Additionally, the World Bank trained CNAAS professionals and civil servants from the ministries of agriculture, finance, fisheries, forestry, and transport about index insurance – another step to ensure that this financial technology could be pushed forward nationally.

The World Bank also operated at the regional level, particularly at the Inter-African Conference of Insurance Markets (or CIMA in French), which regulates the insurance market in several African countries. The World Bank conducted influential lobbying to have microinsurance and index insurance for agriculture authorized so that these technologies could spread throughout the continent. This led to the reform of the CIMA Code,<sup>3</sup> the ratification of new regulations in the CFA franc zone, and the labeling of Senegal and Benin as pilot countries for the implementation of these regulations. To sum up, the World Bank built the institutional and regulatory framework for the deployment of index insurance not only in Senegal but also more generally in Africa.

The role of USAID was also structuring, but it highlights another dynamic. Since 2009 and the launch of two US development programs in Senegal, the first called ‘Economic Growth Project’ and the other ‘Naatal Mbay,’ USAID had been working to modernize agricultural value chains around specific crops (maize, rice, and millet). The value chain approach consists of professionalizing farmers and structuring agro-industries: strengthening farmers’ organizations; pushing for the use of certified seeds, fertilizers, pesticides, and other chemical inputs; distributing technical equipment and digital technologies; offering management training to farmers’ organizations; and encouraging the use of dedicated loans to invest in

their means of production. In short, it is an agricultural modernization project that targets grassroots organizations, in which index insurance was progressively included as a new form of security for entrepreneurial farmers.

Another USAID contribution was to turn index insurance into collateral for agricultural loans locally, a bundling scheme primarily developed at the global scale. USAID encouraged partnerships between the insurance tandem and rural banks to offer insurance to farmers who purchase loans and micro-credits. This scheme was meant for a specific category of farmers operating in commercial agriculture to access formal credit and secure the loans, in case their production is impacted by rainfall deficit and prevent them from paying back their debt. These commercial farmers are of interest to USAID because they are the potential users of certified seeds and inputs at the center of the US Agency's agricultural model. Since these agricultural technologies can only be purchased on credit, making insurance the collateral of loans is a way to secure farmers' investments year after year. Johnson's research (2013) is of great help with understanding this collateralization as a way to secure farmers against an environmental risk (putting them 'at risk'), in order to increase economic risk-taking for a productive objective (so that farmers could be 'risk capable'). At the center of this subjectivization process, the abstract technology of insurance turns an environmental danger into a transferable intangible, which can circulate thanks to financial institutions.

In short, index insurance in Senegal is a market 'under aid' (Provini and Schlimmer 2016), i.e. rooted in the expectations, standards, and capital coming from international aid agencies, which fund the vast majority of the program. Development agencies subsidize individual premiums in their respective pilot projects, adding dedicated funding to the state's subsidies they initially recommended. They also fund the research and development work conducted to implement index insurance's infrastructure and pay for the technologies it requires, as we will see in the next section. These investments do not appear in the insurer's balance sheet and give, at least on paper, a flawed idea of economic sustainability.

## **An infrastructure to produce an insurable 'rainfall deficit'**

Among these various investments, international development capital also contributed to funding a central feature of the environmental market infrastructure: the meteorological technologies producing geo-referenced rainfall data upon which index insurance operates. It is crucial to critically understand that these technologies allow index insurance to select a very small portion of the physical reality of drought and produce abundant data about it in order to make it insurable.

Index insurance was technically designed to answer the challenges of new markets. It promises to automatize both claim management and environmental data collection to overcome the insurance industry's lack of trust in emerging markets. Index insurance offers an alternative to loss reporting by the policyholder and the certification of such loss by an expert appointed by the company. This alternative lies in the use of a proxy. As the actual loss is not reported nor certified, a meteorological technology measures rainfall, and its data is used to build the index upon which the compensation scheme is based. If index insurance is marketed as a financial protection against drought, 'rainfall deficit' is the actual risk insured. The index sets rainfall thresholds, which serve as proxies for losses and are used to calculate premiums. A network of rain gauges was gradually installed for the sector to compile geo-referenced data. They were set up in strategic sites in Senegal's rain-fed agricultural zones to offer insurance to farmers with fields located within a 5 km radius surrounding a given gauge.

This radius constitutes the ‘Unit Area of Insurance,’ or UAI. Another key feature is that the contract is divided into several temporal phases related to the agronomic modeling of the water needed to grow a given crop, at different stages of its development. If the amount of rainfall recorded by the rain gauge falls below the threshold established for a given crop at a given phase, the index ‘triggers’ and the policyholder is compensated for his or her possible loss without any assessment from the insurance company. These procedures are expected to offer a cheaper and more reliable solution than traditional insurance schemes as, in theory, fewer human intermediaries and more technologies are involved.

As it targets a climate risk in agriculture, index insurance requires an environmental market infrastructure based on meteorological data and agronomic modeling. If research on insurance schemes based on weather data can be dated back to the 1950s (Halcrow 1949, Lee 1953), project-oriented research conducted by development experts in the last 20 years contributed to the rise of index insurance. The first technical reports and academic articles about the design of rainfall-deficit indexes for agricultural insurance were published in the early 2000s (Varangis *et al.* 2002, Stoppa and Hess 2003, Skees and Barnett 2006). Around the same time, pilot projects for actual market development were realized in India and Mexico in 2003, in Malawi and Nicaragua in 2005, and have proliferated since then. In Senegal, data collection, as well as product and pilot designs, were conducted in 2007–2008, when the World Bank commissioned an agro-climatologist from CIRAD, the French agency for agricultural research and international cooperation. The goal was to build an index dedicated to the regions and crops targeted by the Bank, specifically groundnut and maize production in the Siné Saloum. This work ended up being published as the first technical study on this subject in Senegal (Mahul *et al.* 2009).

Rainfall deficit indexes are individualized for specific crops, based on the distinction of various phases in the plants’ growth: sowing, vegetative phase, flowering phase, and seed development. Each of these phases is associated with a value established by a water-balance crop model developed by CIRAD and the Sahelian Regional Center for Expertise, Agricultural Development and Adaptation to Drought, to model the minimum water requirements necessary for the crop to grow. Insurance premiums and payouts are calculated with respect to these different rainfall thresholds and according to various geographical areas (see Table 1).

<i>Parameter</i>	<i>Value</i>		
Sowing Window	11th June - 20th July		
Rainfall Sowing Trigger (when the policyholder has to start sowing)	30 mm of cumulative rainfall within a 10-day period		
Rainfall Cap (the index does not consider additional levels of rainfall, because too much rain can damage the cultivation)	70 mm of cumulative rainfall within a 10-day period		
	<i>Phase 1 - Establishment</i>	<i>Phase 2 - Vegetative Growth &amp; Flowering</i>	<i>Phase 3 - Yield Formation &amp; Ripening</i>
Phase Lengths	30 days	40 days	30 days

Phase Trigger Level (rainfall levels below which insurance compensation begins)	55 mm	155 mm	40 mm
Phase Exit Level (below which a maximum payout is due to the policy holder)	20 mm	30 mm	5 mm
Phase Tick (fixed payout per hectare for each mm below the trigger level for that phase)	3,671 CFA francs/ha/mm	1,144 CFA francs/ha/mm	4,571 CFA francs/ha/mm
Phase Maximum Payout (per farmer per hectare insured if less than or equal to the phase exit level)	128,500 CFA francs	143,000 CFA francs	160,000 CFA francs
Contract Maximum Payout (for the 3 phases)	160,000 CFA Francs		
Indicative Technical Premium (estimated price of the premium, without potential additional fees from the insurer or brokers, for the 3 phases)	15,800 (9.9%)		

**Table 1. Prototype of a contract for fields located in the Niore area (adapted by the author from Mahul *et al.* 2009, p. 81).**

From the perspective of a policyholder, the price of insurance will depend on the type of crop (such as groundnuts, maize, rice) the type of seed (short-cycle or long-cycle variety), as well as the geographical location of the farmer's field, since the drier the area is, the more expensive the premium will be. The amount up to which the farmer will insure his or her hectare (from CFAF 25,000 to 200,000, i.e. from 38 to 300 euros) is also taken into account. Finally, the price of the premium is also affected by the annual variation of the index (or 'redesign'), which is updated each year according to new rainfall data in the database. Good years reduce the price of premiums; bad years increase them. All these variables were established, defined, and specified by crop types, by seed types, and by villages. This meticulous work was the task of experts commissioned by the World Bank and was established and compiled into a digital spreadsheet also provided by the World Bank. Since then, this spreadsheet has acted as an actuarial model for Planet Guarantee, whose in-house climatologist runs the model with data from ANACIM, Senegal's meteorological agency. This tool is recalibrated for every new pilot project. As experimentation with index insurance has increasingly happened in new regions and with new crops, the infrastructure has not changed, but the variables are updated and new ones are created. Since the first World Bank pilot project in 2012, its overall logic has not changed much despite some evolution in the product.

Once the actuarial model is in place, index insurance is highly dependent on geo-referenced rainfall data. Informational inputs are crucial, as data quality should prevent 'basis risk.' Basis risk is an important concept in index insurance, encapsulating the possibility that the insurance infrastructure does not spot the actual loss suffered by the policyholder. As index

insurance replaces loss declaration by a technological proxy, basis risk is one of the most critical problems emerging from this new scheme. Indeed, Johnson has shown that basis risk is the remainder that policyholders are supposed to bear, a ‘disjuncture between experienced versus recorded loss events’ (2013, p. 2675). Basis risk occurrences are often related to meteorological instrumentation (which might be defective and fail to grasp weather conditions); to index design (if the temporal phases or product triggers are poorly calibrated) or to the distance between the rain gauge and the farmer’s field (an event recorded by the rain gauge might not have happened in a field nearby). Even with the UAI of 5 km around the rain gauge as the conventional unit chosen to establish compensation schemes, it is a sensitive parameter as rainfall variability is very high in the Siné Saloum region.

One could be surprised to see Senegal’s investment in ground infrastructure since most index insurance projects worldwide use remote sensing technologies.<sup>4</sup> Their relatively low cost explains that preference – data is sometimes free – and the fact that the insurance industry is very familiar with using them. Moreover, Senegal opted for rain gauges because when index insurance’s meteorological infrastructure was under construction in the country in the late 2000s, ground infrastructure was seen as offering more robust data. At the same time, satellites were considered as an indirect measurement tool operating by proxy, in the sense that it can only offer a visualization ‘from above’ of the rainfall in a given area. If how exactly the choice of rain gauges was made is unclear to me, various actors claimed in interviews that at the time of the first pilot, a direct measurement of the rainfall on the ground was the best way to minimize basis risk. Consequently, the World Bank installed the first rain gauges in the Siné Saloum region, and then every development agency funded more of them to amplify the network, which resulted in covering all the country’s main productive areas.

The coverage of Senegalese rural areas with rain gauges was phased in gradually and negotiated among development agencies, the insurance tandem, and ANACIM. Rain gauges are installed following specific norms<sup>5</sup> on the outskirts of the villages and are enclosed by a wire fence to protect them from people and animals. The most recent rain gauges operate through the GPRS network (equipped with SIM cards), and data is sent to the server at ANACIM’s office in Dakar (Figure 1).

What is more complicated is the whole logistics, meaning managing the data. Because it involves automatic rain gauges... Why automatic? Because that is the implicit demand of insurers: when it says automatic, it means “no fraud,” in theory at least, so that’s it. So, the logistics is the weak link, it is the difficult point of the system, because it requires investment, and it requires operating, maintenance and organization, management, and supervision costs... So, fortunately, development agencies pay for these investments.

Agro-climatologist at CIRAD, interview by Skype on 07/03/2017.

Data security is considered crucial, which explain why this interviewee thinks the automatic sending of data by rain gauge as the answer to ‘the implicit demand of insurers’ about the risk of fraud. Indeed, local intermediaries are always considered a threat to the proper functioning of the market’s information system. In a way, rain gauges serve multiple ends: they produce the risk of rainfall deficit by extracting it from the physical environment, but they also satisfy the moral and economic valuation of powerful actors who do not want people to be involved in data production. Data sociologists have suggested (Denis 2018) that automation is a mere illusion, as such processes always require invisible data maintenance to be involved, as we will see in the next section. Although, we can already note here that automation also requires

a specific discipline of people and other elements (processes, technologies, objects) demanding both the creation of a specific social order (behaviors, controls, maintenance) while circumventing other practices. The race for the production of rainfall data was far from over at the time of my fieldwork in 2017, and the Director of the Naatal Mbay project (USAID) had just then obtained funding from the Canadian development agency, CIDA, for nearly 200 additional rain gauges to cover the entire south of the country.



Figure 1. An automatic rain gauge in the village of N'Doffane (picture from the author).

Finally, with a map, we made small circles with a radius of 5 km, and we realized that by focusing on the productive areas we know of... And well, to cover most of the maize, the rain-fed rice, groundnuts, and all that... we needed a total of about 280 rain gauges. And we had already supported a pilot project with the World Bank, which already covered about 60 of them, maybe more, so we needed about 200 more rain gauges to cover the whole of southern Senegal. So we simply lobbied a little, and Canada agreed to pay. The costs can be covered by a \$1 million donation, it's less than €1 million.

Interview with the USAID Project Director, Dakar, 26/09/2017.

This quote shows that the infrastructural equipment was continuously considered by donors as strategic to develop the market and target new areas for both their productivity and their vulnerability. Such a reductionist and expansionist gesture is typical of the developmentalist

viewpoint (Scott 1998), as the physicality of the milieu is drastically reduced and circumvented while the production sites of environmental intangibles are expanded.

What is the risk of rainfall deficit when it is produced through such infrastructure? Also, what characteristics of environmental intangibles can be drawn from this case? First, *risk is defined according to an agronomic norm*: it is crop-based. As a ‘deficit,’ the risk is built in relation to a schematic understanding of a plant’s agronomy, more precisely of the average water needs of a specific crop at several stages of its growth. Therefore, the index, therefore, materializes the risk by setting conventional rainfall thresholds below which agronomists consider that a crop is not able to develop. Modeling technologies are central in that regard and contribute to the reductionist gesture of index insurance. Second, *risk is zoned, but not local*. ‘Rainfall deficit’ is indeed attached to a locality, thanks to the grounded meteorological network. In the non-irrigated areas, for which index insurance is designed, risk pricing largely depends on the geographic data produced by the gauges. Territorial zoning and meteorology are intertwined in the rain gauge network, which acts as a downscaled weather infrastructure (Edwards 2016). As rain gauges conventionally cover a 5 km radius, the thresholds defined for a specific area and a specific crop will determine the exact amount of compensation that a farmer would receive, and the time frame within which the risk is insured. The zoning of the risk is also important because it produces localized rainfall data to Planet Guarantee and CNAAS, which can then conduct sensitivity testing on the index to adapt the price of premiums based on historical data. Although zoned, the risk is not local because the main goal of the infrastructure is to extract it from its physicality and specificity and to make it an abstraction that can circulate. As with other insurance technologies, index insurance performs such abstractions to aggregate, evaluate, and spread risk. Third, *the risk is produced so as to be transferable to the market* – making it an environmental intangible. The environmental risk is commodified through a contract, which makes it transferable from the policyholder to the insurer and the reinsurer, for which the bearer expects a premium. These characteristics contribute to the understanding of environmental intangibles. They were shaped by specific environmental knowledge that has been integrated into the insurance rationality. Also, the insurance intangible is attached to territories through conventions and earth-surveillance technologies but is not local, and it is built to circulate on the market. All of this means that the data about risk also has to circulate, and that risk transfer has to be of interest for various economic actors, which is often a challenge.

## **A ‘mad white elephant’: when the environmental intangible faces infrastructural challenges**

Index insurance promises that ‘rainfall deficit,’ once correctly measured in the field and extracted, indexed, and contracted into an insurance policy, could support the risk transfer. As with other insurance innovation for climate risk, environmental intangibles are the keystone to safeguard the trust of public institutions, private actors, and investors (Angeli Aguiton 2018). Nevertheless, in practice, these promises are far from being fulfilled, and index insurance is – unsurprisingly – much more complicated than it seems because the market did not reach the expectations of the insurance tandem, or the development agencies. During my fieldwork phase, about 16,000 contracts were sold, which represent 10% of the expected sales. The market’s obstacles led various actors to express their views on the difficulties that they encountered. There are three kinds of difficulties: challenges in data production (breakdowns and conflicts), in the distribution scheme, and in risk valuation among the insurance tandem and the global reinsurance industry.

Once rain gauges are settled in the fields, maintenance is required. ANACIM sends a team twice a year to check and fix the rain gauges in the fields and manually collect the data when it is not transferred via the GPRS network.<sup>6</sup> Other maintenance operations managed by ANACIM concern the quality of data itself, as they need to be checked by meteorologists before they are transferred to CNAAS and Planet Guarantee to produce sheets in time for post-seasonal claims management. This process is far from being straightforward, as the climatologist from Planet Guarantee suggests:

[GPRS transmission rain gauges] have chips [phone SIM cards], and if we have to install them in an area, we have to make sure that ORANGE, TIGO or Espresso [Telecom] operators [cover the area], because rain gauges are connected to the phone network... Sometimes there are areas where, whatever the operator, because of the clouds, [the rain gauge] does not receive well, the network does not work well, and as a result, the data is lost. So we are obliged to go through ANACIM [the meteorological agency]... [Additionally], as it is a whole network, and that rain gauges are located everywhere in the Niore area... it is a large space, and therefore ANACIM must move around, but it cannot do so every day, so they organize missions that are a little spaced out... But it's not automatic, that's the danger, [sometimes] you have to wait until the end of the winter to realize what happened.

Interview with a climatologist at Planet Guarantee, Dakar, 12/10/2017

The data collected from the GPRS network is technically challenging: the mobile network can have breakdowns, clouds often block the emission of data, and the gauge can have a power or memory problem. These maintenance problems can be complicated even more by the division of labor among actors. ANACIM is the only entity with authority over the rain-gauge network and the data, but the agency has few internal resources and many tasks to fulfill. Consequently, the processes of data collection, cleaning, and circulation are often delayed, which create tensions among the insurance tandem, the meteorological agency, the international donors and, in the end, with the policyholders, if the delays impact claim payments.

Tensions also occur in market construction, which is the second type of challenge faced by index insurance. The marketing strategy initially chosen to sell insurance to farmers relies on using farmers' organizations as resellers of index insurance. Yet, the training and commission fees for these intermediaries raise a scalability issue for the insurance tandem. This relates to the materiality of market construction as, in addition to the costs related to the meteorological infrastructure, those related to financial literacy and marketing are very high.

We have conversion rates of 40%... So, you have to go and talk to 50,000 people to sell 20,000 policies How much will it cost you? It's very expensive! We have paid for research centers, we have paid for satellite data, for wages, for premises, etc. But where we put the most money is on the guys [sic.] who do the training sessions. (...) And it's not in our [business] model, we won't be able to do this forever (...) There, we have almost 90 distribution networks [i.e, farmers' organizations in charge of marketing insurance on the field]: so 90 structures, which you must call on the phone because it's the deadline for the reporting, then you must correct the report because it's badly filled, then you must validate, then you must recover the payments... So it's a mad white elephant! And there are eight of us [in Planet Guarantee], and there are two of them [in each farmers' organization] taking care of that: so it's not a model that we can scale up.

Interview with the Director of Planet Guarantee, Dakar, 23/09/2017.

While promoted as automated and cheaper than traditional insurance, the positioning of farmers toward index insurance was left entirely unquestioned by development agencies. However, after several years of pilot projects, the challenges became obvious: the primary market renewal every year, the contract management, and then the financial literacy activities were time-consuming, very expensive, and quite ineffective. Selling agricultural insurance is labor-intensive, as I have shown in another article (Angeli Aguiton 2019). Risk transfer is not a smooth and automated process, and the insurance tandem had to organize a dense network of farmers' organizations to sell insurance and report every contract signed in the field to Planet Guarantee. As suggested in the above quote, this process is burdensome, expensive, and the market would not sustain without development capital supporting these additional fees.

Finally, the third type of challenges relates to the difficulties of the insurance tandem to meet market standards and requirements expected by the global reinsurance industry. From the beginning, this was a challenge for the broker Planet Guarantee when negotiating reinsurance contracts with a large European reinsurance company.

The problem was that [the reinsurance companies] arrived in extremely underdeveloped markets with international standards. So, in a way it was great (...) it pulled the thing up, but...if you think about what it means in terms of reporting deadlines, of product pricing... [When they checked the books] they don't just verify where you put the comma, they do a 10-digit verification after the comma, with the biggest brains of Switzerland... [We faced] a lack of flexibility and a [reinsurance] price that was really too expensive.

Interview with the Director of Planet Guarantee, Dakar, 23/09/2017.

The global insurance industry's actuarial practices do not accommodate the bricolage needed for an emerging market such as index insurance in Senegal. Following the industry and in-house standards (Jarzabkowski *et al.* 2015), the reinsurance industry constantly reassesses the technical premium on Senegalese farmers' risks and asks for a higher premium to reinsure them. Such struggles over risk calculation resolved when the World Bank decided to intervene (Angeli Aguiton 2019). As the World Bank project manager in charge of insurance development in West Africa related in an interview, this was fixed first by paying part of the reinsurance premiums itself, and by doing so, using development capital in the service of the reinsurance industry. In addition, they negotiated a lower price from reinsurers by asking them to make 'a commercial effort.' This market 'under aid' endures thanks to development agencies using their capital and negotiation power.

These challenges relate to the simultaneous construction of the market and the environmental infrastructure on which index insurance runs. Data production and maintenance are labor-intensive, often underestimated by organizations (Denis 2018, Barral 2020 in this special issue), and create coordination problems among actors. These problems are exacerbated by the fact that insurance does not sell well. Consequently, that risk transfer has to be negotiated at the two ends of the market, to ensure that farmers agree to transfer their risks and that reinsurers agree to bear them for an affordable premium. It also highlights that, in a market under aid, the capital required to make risk circulate is not only the premium calculated by actuaries. Development money circulates at every level to subsidize farmers, train employees in farmers' organizations, equip ANACIM with automatic rain gauges, ensure that CNAAS

remains solvent, cover Planet Guarantee's mounting costs, and also control the price of reinsurance premiums. These infrastructural costs are often unacknowledged and concealed behind the branding of automated information systems, even though they are necessary to ensure that rainfall risk is actually transferred.

## **Towards an infrastructural shift? <sup>7</sup>**

The environmental market infrastructure was also blamed for these challenges, and rainfall data was targeted as one of the features to improve. In 2011, when the first World Bank pilot project launched, rain gauges were considered less prone to basis risk than satellites, and recording rainfall from the ground, they were expected to trigger claims more accurately in case of an event. However, while rain gauges were funded and installed in various areas of rural Senegal, remote-sensing technologies for index insurance improved, often supported by the same international development programs as the ones running in Senegal. In the global index insurance community, critics progressively targeted rain gauges. The technology was accused of being labor-intensive and limiting the scaling up of the market. The different densities of rain gauge networks among countries were depicted as too important to allow transnational initiatives and commensuration, while the maintenance and coordination of field data were considered too challenging. In parallel, the improvement of satellite resolution shifted the blame of basis risk back to the rain gauge system. Additionally, the remote sensing scientific community and the insurance industry worked at improving satellite data for index insurance. Workshops, studies, and joint initiatives were dedicated to adapting satellite data to the needs of insurers. These included specific temporal and spatial resolution, low latency, sufficient length of records, and user-friendly access – for an example of such initiatives, see Black *et al.* (2016).

This global trend toward remote sensing was also fueled by an extensive study conducted in Senegal by the International Fund for Agricultural Development (IFAD) to improve satellite technologies for index insurance globally. The study solicited the expertise of most of the local index insurance actors and was funded by various international partners, including the World Bank and the World Food Program. The final report claims that

limited availability, accessibility, quantity and poor quality of data on the ground are some of the primary technical constraints preventing scale-up and sustainability of index insurance ... These inconsistencies intensify vulnerability, lead to distrust of insurance, and ultimately have an impact on demand. (IFAD 2017, p. 9)

If this conclusion aimed for a global reach, it had a direct implication for index insurance in Senegal, signifying that infrastructural change needs to occur to meet the ambitions of the market.

Such conclusions may seem paradoxical considering the investments already made in Senegal. Yet, locally, the rain gauge network was considered by some as disproportionate in scale. Then again, dismantlement was not an option as remote sensing was presented as the most robust infrastructure, and new functions and justifications for rain gauges emerged. This contrasting dialectic of infrastructural blame and promise is at play in the Director of Planet Guarantee's discourse:

Senegal will become the country with the highest density of automatic rain gauges in the world, at least in Africa, that is clear, but eventually in the world. Because in fact, from a

research point of view, and from an agronomic point of view, it doesn't make much sense to have such a density of rain gauges. It requires maintenance, surveillance... So, from an economic perspective, this is not a very smart thing to do. But it answers a basic need: we are not yet positioned on satellites, and [the rain gauge network] will be a huge tool to calibrate remote sensing tools, because when you have a lot of ground data, it's really easier to calibrate satellites.

Director of Planet Guarantee, interview in Dakar, 23/09/2017.

This quote calls for two comments. The first one concerns the new functions acquired by rain gauges through the infrastructural change. Because rain gauges are considered as too limiting and work-intensive to equip a mature market, their role is reassigned as a tool to calibrate remote sensing data. This is an illustrative pathway towards infrastructural embeddedness (Star and Ruhleder 1996) as the ground infrastructure is embedded in the remote sensing infrastructure. It also highlights that the global strategy for expanding the market has material consequences for its own infrastructure: ambitions for scaling up (also) concern meteorological instruments, and if field data is not robust enough to support the market, they can assist satellite data to do so. With this layering of data sources, environmental market infrastructure can be seen as the tangible materialization of the changing visions of both global and local economic actors.

The infrastructural shift toward satellite data, however, might not solve market challenges and could even create some new issues. As the IFAD study shows, the quality of satellite data varies across crops and geographical areas, and still largely depends on the quality of rain gauge data and agricultural yield statistics. Additionally, the zoning of the risk (through the conventional Unit Areas of Insurance) still raises basis risk concerns.<sup>8</sup> In answer to these issues, the report calls for an improvement in the quality, accessibility, and interconnection of ground, satellite, and historical data; for further operational research on UAI on long-time series provided by satellite data and for technical support dedicated to the maintenance of the infrastructure. If further empirical research is necessary to trace such implications, these recommendations suggest that challenges in the products' functioning might endure even with remote sensing technologies. Additionally, we can consider that even with satellite data, the automation of index insurance is still a mere illusion, as the 'invisible work' of data maintenance (Denis 2018) on the infrastructure is very much at stake.

The second interesting comment made by the Director of Planet Guarantee in the previous quote concerns the fact that the use of rain gauges for purposes other than index insurance was, from the start, very limited. ANACIM, Senegal's meteorological agency, had no use for automatic rain gauges before index insurance was launched. It produced data through its own weather stations (measuring various phenomena other than rainfall, such as temperature, pressure, wind speed, and orientation). Even though rain gauges were not a central piece in its own meteorological instruments, index insurance pilot projects put them at the center of ANACIM's new mission. The agency was commissioned to maintain the environmental market infrastructure and to collect the data and transfer it to the insurance tandem to calculate claims and redesign the index. As the meteorological agency saw its mission redefined by the rain gauges, one can wonder how the infrastructural switch toward remote sensing data might affect ANACIM. Early findings suggest that another application for Senegal's rain gauges could lie in the development of 'climate services,'<sup>9</sup> a new market strategy created by ANACIM to commodify weather data. In that sense, index insurance might have been only the first environmental intangible to be developed through the

infrastructure, which is considered as a potential support to various markets. This points to another feature of environmental market infrastructure. Standardized and straightforward, environmental intangibles are expected to become economically productive for various ends, reinforcing the trend towards a ‘climate service business model’ in development economics and politics (Webber and Donner 2016).

## Conclusion

This paper has investigated the production of a drought ‘that capital can see’ (Robertson 2006, p. 367) through the specific abstraction of ‘rainfall deficit.’ This abstraction supports index insurance, which promises to expand the insurability of environmental risk in agriculture in the Global South, by automating rainfall data collection and claim management. Such an intangible requires standardization and coordination and relies on an environmental market infrastructure designed to produce, simultaneously, robust environmental data and future policyholders. Such infrastructure interconnects multiple spaces and temporalities through which ‘rainfall deficit’ can travel. These factors range from the fields where rain gauges are installed to global reinsurers’ books, the support and multiple adaptations of ANACIM’s meteorological network, the agronomic models, the insurer’s coding sheets, not to mention the structuring presence of the World Bank and USAID.

The construction of index insurance in Senegal, the challenges met, and the ‘improvements’ underway, highlight the fact that environmental intangibles in the development context are produced through a regime of experimentation – and achieved with publicly funded short-term pilot projects, feasibility studies, and low economic profitability presented as acceptable. It is also embedded in a regime of infrastructural development, intending to establish large socio-technical, juridical and financial systems that are expected to sustain the market in the future, and sometimes even to serve future markets to emerge. The shift from rain gauges to remote sensing shows that infrastructure is also considered as an object of experimentation. Such articulation of experiments and infrastructure related to environmental intangibles is not paradoxical – but instead suggests that in these new trends of development, international agencies materially equip and support fragile markets, rather than contribute to the construction of welfare policies alongside national governments. In this process, the challenges and failures encountered by index insurance can probably be better understood as iterative trials aimed at articulating new data production on climate risks, corporate interventions, and prototypes of development. In such attempts, the environmental market infrastructure of rainfall deficit solidifies through different layers. If the local market does not scale up, the global infrastructure of index insurance grows through various sites all around the world.

The issue at stake is also political. As index insurance is central to the current governmentality of climate change performed by international development agencies, it benefits from the political and financial support that helps it face obstacles. Even though index insurance would probably have been abandoned in other contexts, it is still operating in Senegal and reinforces the role of financial securitization techniques in the political regulation of environmental risks. Additionally, as a technology for rural development in the Global South, index insurance is part of a broader set of financial tools aimed at producing a new profile of farmers ‘created by virtue of their status as financial consumers of risk-transfer products’ as Johnson puts it (2013, p. 2665). As such, this kind of environmental intangible also plays a role in the governmentality of agricultural practices, and productivity is expected

to derive from new technologies of financial-environmental security (Chiapello and Engels 2020 in this special issue).

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## Notes

1 The World Bank launched the first initiative in 2011 through a pilot project to insure groundnut and maize productions in the Siné Saloum region. It was followed by a project of the United States Agency for International Development (USAID) on maize, millet, and rice. Then, the World Food Program (WFP), the United Nation’s international food aid agency, launched a multi-grain insurance pilot in 2014. The European Union added its contribution in 2017, with an insurance scheme for five cereals (millet, cowpea, sorghum, rice, and maize). The West African Development Bank (BOAD) launched a project on maize and cotton in 2017. The main areas covered are mostly located in the Siné Saloum and Tambacounda regions, so pilot projects are geographically concentrated. These donors have created a structure, the Committee for the Development and Promotion of Index Insurance, through which they coordinate their efforts in collaboration with Senegalese institutions and the insurance company, in order to transform their experimental intervention into a lasting dynamic.

2 An insurance premium is the amount paid by the policyholder for the insurance contract.

3 With the addition of a new rule-book in the CIMA Code entirely dedicated to micro and index insurance.

4 Three main indexes have been developed: the Normalized Difference Vegetation Index (or NDVI, which focuses on plant cover), evapotranspiration (which measures the amount of water that evaporates from the soil, and infers from it the amount of water present in the soil), and the Rainfall Estimate (which focuses on rainfall).

5 In particular, the guidelines established by the World Meteorological Organization regarding the clearance of the site, its security, the size of vegetation, the height of the gauge, etc.

6 It was noted earlier that the most recent rain gauges automatically send their data to the ANACIM office in Dakar through the GPRS network. This was not the case with the first

generation of rain gauges, which required ANACIM agents to physically visit each gauge twice a year in order to get the data stored in a hard drive.

7 I am truly indebted to one of the anonymous reviewers of the *Journal of Cultural Economy* for the precious suggestions that encouraged me to develop this argument, I would like to thank her/him sincerely.

8 The geographical units, which serve as a base for payouts, are highly dependent on the instruments used for their measurement. In this paper, these units are defined as the 5 km surrounding a rain gauge. But this unit differs with remote sensing technologies, which require adjustments to the instruments and conventions in the contracts in order to mitigate basis risk.

9 Examples of commercial climate services developed by ANACIM are: the production of localized weather forecasts that are broadcast on local radios and sent by text-messages to farmers (supported by the CGIAR), or the creation of an online geo-portal, which produce climate simulations to feed decision support systems for agriculture, water management, etc. (supported by a consortium of Senegalese, French and UK research and development agencies).

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