



**HAL**  
open science

### 3 Managing the Combined Hazards of Rainy Season and Flooding in the Absence of Planning: Agriculture in the Flood-Prone Areas of Kilombero and Lower Rufiji (Southern Tanzania)

Hubert Cochet, Jean-Luc Paul, Céline Tewa, Philippe Le Clerc

► **To cite this version:**

Hubert Cochet, Jean-Luc Paul, Céline Tewa, Philippe Le Clerc. 3 Managing the Combined Hazards of Rainy Season and Flooding in the Absence of Planning: Agriculture in the Flood-Prone Areas of Kilombero and Lower Rufiji (Southern Tanzania). *Agrarian Systems and Climatic Change. Journeys of adaptation in the Global South*, 2024, 10.1079/9781800628137.0003 . hal-04901105

**HAL Id: hal-04901105**

**<https://hal.science/hal-04901105v1>**

Submitted on 20 Jan 2025

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# 3 Managing the Combined Hazards of Rainy Season and Flooding in the Absence of Planning: Agriculture in the Flood-Prone Areas of Kilombero and Lower Rufiji (Southern Tanzania)

Hubert Cochet<sup>1\*</sup>, Jean Luc Paul<sup>2</sup>, Céline Tewa<sup>3</sup>, and Philippe Le Clerc<sup>4</sup>

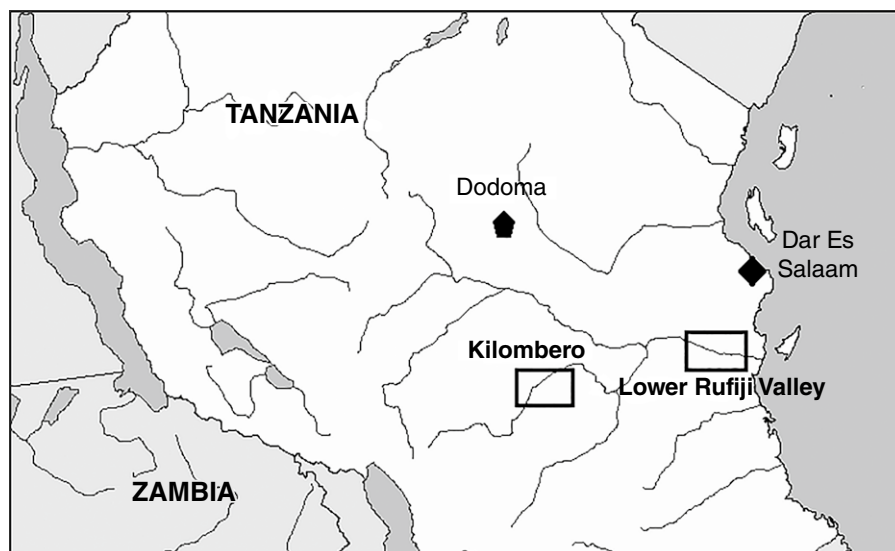
<sup>1</sup>Comparative Agriculture Training & Research Unit/UMR Prodig, AgroParisTech, Palaiseau, France; <sup>2</sup>Associate Professor of Anthropology, Institute of African Worlds, University of the French Antilles, France; <sup>3</sup>Founder of the Zero Waste 'Les Gamelles' network; <sup>4</sup>Rural development and Food security Program Manager, European Commission, Delegation of the European Union to Mauritania

Two regions were identified to address the case of flood-prone, rice-growing areas with low levels of planning: first, the lower Rufiji River Valley in southern Tanzania, and second, the Ifakara region on the Kilombero River, a tributary of the Rufiji (Fig. 3.1). These two small regions offer an excellent opportunity to reflect on how farmers can consider the risks associated with climatic hazards. Farmers are confronted with two types of hazards, both related to climate: first, rainfall volume and distribution (date of the first significant rainfall, distribution of subsequent rains), and second, flood volume and timing (location, duration), on which the areas harvested, effectiveness of fertilization (deposition by the flood), and yields obtained depend. These regions are also part of the development “corridor” advocated by SAGCOT (Southern Agricultural Growth Corridor of Tanzania), where different agricultural models (family farming and large-scale investment projects, including rice cultivation plans) are combined.

## 3.1 Rufiji River Flood Valley and Tributaries in Southern Tanzania

Projections of possible rainfall change in East Africa are relatively uncertain and do not make for a very clear trend (Chapter 2, this volume). Although southern Tanzania is one of the regions for which a rainfall increase is considered likely (Kilembe *et al.*, 2012), we will see that recent rainfall trends in the two regions studied call for caution: a clear decrease in rainfall is well documented in the Rufiji River’s lower valley, but upstream, in the valley of its tributary, the Kilombero, the trend seems to be more upward (see below). This region of East Africa is also one that would be affected—all the models converge on this point—by an increase in the frequency and intensity of extreme events, particularly floods. The years 1997, 2007, and 2014 bear witness to these extreme events.

\*Corresponding author: hubert.cochet@agroparistech.fr



**Fig. 3.1.** Location of the study areas in the Rufiji River Basin.

### 3.1.1 Rainfall calendar, flood calendar, and climatic hazards

#### 3.1.1.1 In the lower Rufiji Valley

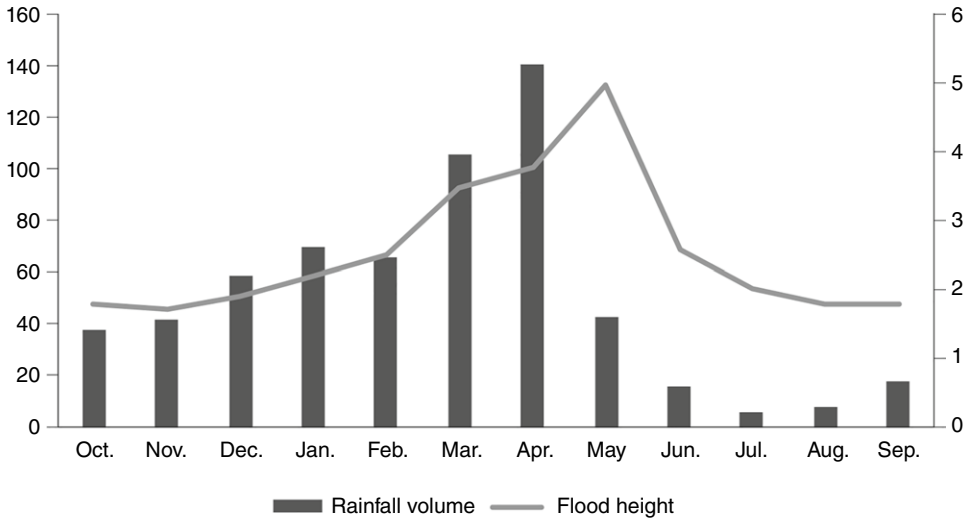
The chart shows a relatively long rainy season from late October to May and a dry season from June to mid-October (Fig. 3.2). In fact, the slight dip in rainfall in February reveals the presence of a short dry period that the average conceals due to its interannual variability. It is the transition between the seasons of “small rains” (*mvuli*) and “large rains” (*masika*). These two seasons are used by farmers to carry out two rainfed crop cycles (mainly corn, but also rice flooded by rain-water runoff). The flood calendar depends on upstream rainfall and is shifted in relation to the local rainfall calendar. At the end of the short rainy season, “flash floods” occur, which can have a destructive effect on the most exposed crops. This period is followed by a brief return to low water and then the main flood. The flood allows for two cropping seasons: the flooded rice crop, which was planted at the end of the short rainy season, and the flood recession corn crop. The rice that will be flooded by the rising water is sown in seed holes, with direct drilling, and when it is dry. The beginning of its cycle is therefore rainfed; it depends on the short rainy season. During the flood, the rise in water level must

therefore be compatible with the speed of the rice’s growth. In the absence of water control, the rice can be submerged (e.g. as in 2013–2014), and it can also wilt at the early stage due to lack of rainfall or later, flooding (e.g. in 2008–2009). In addition, a flood that is too low favors the development of weeds and disadvantages the fertility reproduction of the non-flooded fields.

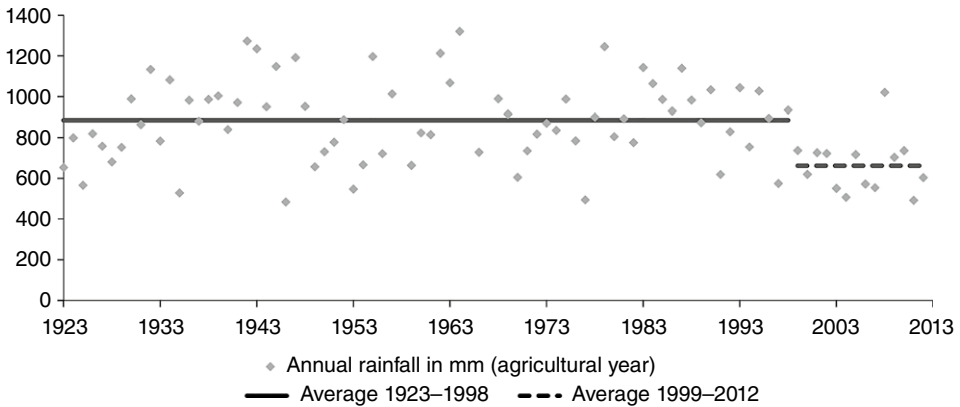
Precipitation is also marked by very strong interannual irregularity. While the average rainfall is 867 mm, the rainfall volume has varied between 500 and 1300 mm over the last decades (Fig. 3.3). Moreover, as the lower valley has been the subject of extensive scientific work in hydrology, fairly precise data on the evolution of precipitation are available, with a significant historical perspective. Duvail *et al.* (2014) highlight a clear drop in precipitation over the last 15 years (Fig. 3.3), with a magnitude comparable to that experienced in West Africa during the 1970s and 1980s (see Chapter 1, this volume).

This sharp decline in rainfall over the past 15 years is widely reported by farmers (Tewa, 2014). Since 1999, rainfall has only once exceeded the average established over the previous period (850 mm). This change is characterized by a significant decrease in rainfall volume and the duration of the short rainy season.

When it comes to the flood’s evolution over time, there are no long-term records available. It



**Fig. 3.2.** Rainfall and flood calendars. Average 1999–2012; flood: average curve shown for information. (From: precipitation: Utete weather station.)



**Fig. 3.3.** Evolution of annual precipitation volume in Utete and average of two periods (1923–1998 and 1999–2012). (From: Duvail *et al.*, 2014.)

is only in the last 15 years or so that Duvail *et al.* (2014) have undertaken accurate measurements. Over the observations' duration, maximum flood height ranges from 6.5 to 4.2 m, a difference of two meters, which has important consequences for agriculture. Flooding is perceived by the population as a benefit and not a disaster (Duvail and Hamerlynck, 2007). It is in fact the basis for the renewal of the flooded fields' fertility, the possibility of flood recession cultivation freed from the rainfall hazard, and the lakes' recharging with water and fish (main fishing areas).

Hamerlynck *et al.* (2010) attempted to answer the question of vulnerability to these hazards. They define three flood situations:

- The “ideal” situation, where the annual flood is in harmony with the region's agricultural system, the probability of such a situation being 0.25 (i.e. once every 4 years).
- The situation where the annual flood does not cover the totality of the flood plain's fields, a situation whose probability would be 0.60 (i.e. 6 out of 10 years).

- The situation of excessive flooding, which causes significant damage to rainfed and flooded crops but ensures a significant extension of flood recession crops and an increase in fishing potential, with a probability of 0.15. The flood of 2014 belongs to this last category. According to the farmers interviewed, no flood of this magnitude had occurred since the 1997–1998 crop year, attributed to the El Niño phenomenon.

### 3.1.1.2 In Kilombero

3.1.1.2.1 RAINFALL VOLUME: INTERANNUAL VARIABILITY AND LONG-TERM EVOLUTION. The rainy season here is more compressed and the rains do not really start until December, later than in the lower Rufiji Valley (Fig. 3.4). On the other hand, rainfall volume is much more consistent here and is in the vicinity of 1500 mm (average for the last 20 years).

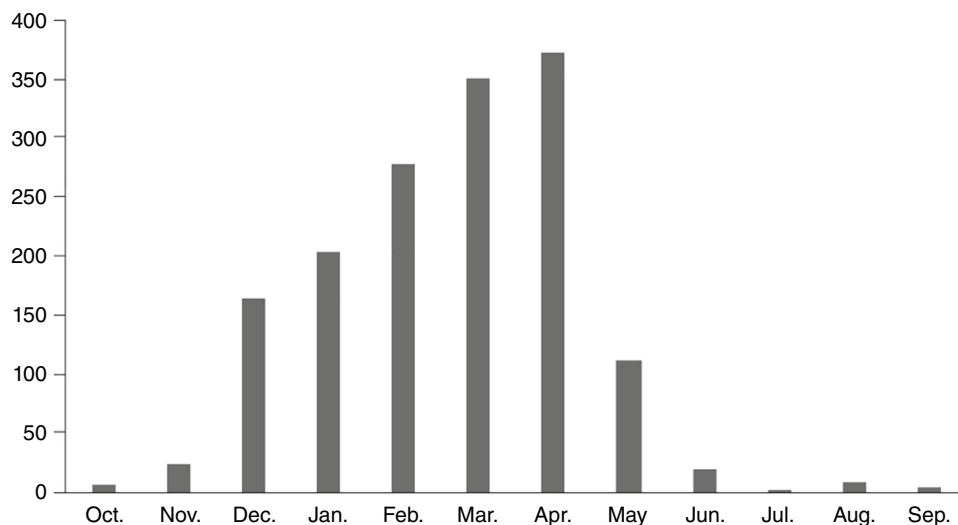
A long series of daily rainfall records (1927–1972), which we were able to obtain from the former Catholic Mission of Ifakara’s experimental station, now closed,<sup>1</sup> as well as more recent series available locally, have made it possible to reconstruct rainfall volume evolution for the last 90 years (Fig. 3.5). It has revealed important

changes and provides a basis for comparison with the testimonies of the people surveyed.

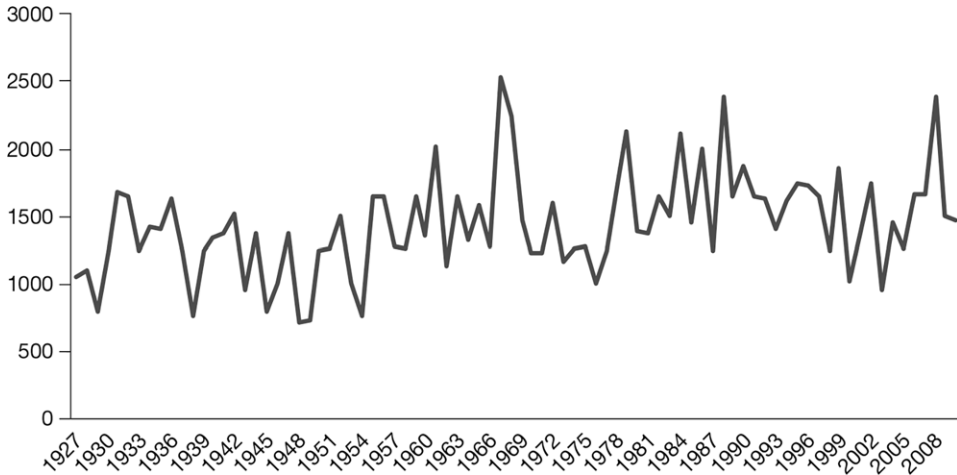
The graph reveals a very high interannual fluctuation in rainfall, ranging from 750 to 2500 mm. Rainfall’s great irregularity is an ancient reality with which the populations have always had to deal. Two recent dry periods are clearly visible: the 1970s, which is well linked to the drought recorded at the same time in the Sahel and which is mentioned very frequently by older farmers, and the more recent, but apparently equally marked, period of the late 1990s and early 2000s.

But the most striking information shown by this graph is a much longer and more marked dry period than the two mentioned above, particularly during the years 1940–1955. Farmers’ current statements, “There is less and less rain today,” must therefore be put into perspective. Their grandparents clearly experienced a worse situation. It would therefore be particularly interesting to identify farmers’ responses to these much drier episodes and to understand the reasons why such adaptation seems more difficult for today’s farmers.

Finally, the trend in recent years would be for an increase in the average rainfall level, and even more so for an increased frequency of very heavy rainfall, as in 2007, 2014, and 2016.



**Fig. 3.4.** Rainfall distribution in Ifakara, Kilombero Valley (2001–2010). (From: Ifakara Rice Experiment Station and Illovo Plantation in Kidatu; graph: authors.)



**Fig. 3.5.** Rainfall trends at Ifakara, Kilombero Valley (1927–2010). (From: Ifakara Catholic Mission 1927–1972 and Rice Research Center 1968–2010 daily climate records; graph: Le Clerc, 2015.)

3.1.1.2.2 SEASONAL RAINFALL DISTRIBUTION: TOWARD A TIGHTENED RAINY SEASON. We have divided this long-term series of daily records into 20-year periods: 1930–1950 (period 1), 1950–1970 (period 2), 1970–1990 (period 3), and 1990–2010 (period 4, Fig. 3.6). We then compared the bi-monthly averages over each of these periods with the most recurrent farmer statements, namely:

- “In the past, we used to see a drop in precipitation in February. This is no longer the case.”
- “The rains’ arrival has shifted: our parents used to sow in December when the first rains came, today this phase takes place in January.”

For the whole 1930–1990 period, February is indeed a time when precipitation ebbs slightly, while over the 1990–2010 period, February precipitation undergoes, on the contrary, a sharp increase (Fig. 3.6). Concerning rainfall’s arrival, today (1990–2010 period) we can see a clear delay in the first rainfall compared to the previous 40 years (1950–1990). This situation also characterizes the 1930–1950 period, with annual rainfall that was significantly lower than today. Farmers’ perception of a delayed rainy season, the consequent tightening of its duration, and the increase in February rainfall therefore corresponds to reality.

3.1.1.2.3 MORE LARGE-SCALE FLOODS. The flood calendar is slightly divergent from the rainfall peak. Maximum rainfall is generally reached at the end of April or the beginning of May with a water level of 4–5 m above the low water mark, or even more than one additional meter in years of very heavy rainfall. Given the valley’s very flat topography and in the absence of any hydraulic planning, interannual variations in the flooded area and the water level’s height are therefore significant. This is a hazard that farmers must manage on the scale of each of their fields.

In contrast to the lower Rufiji Valley (*above*), detailed information on the flooding calendar of the Kilombero and its tributaries is too sparse or too incomplete to be of much use. What remains is the testimony of elderly residents of flood-prone areas since the 1940s stating that no floods comparable to those of 1997 and 2014 (both associated by climate scientists with the El Niño phenomenon) have occurred before (Le Clerc, 2015). More generally, many farmers state, “We are seeing heavy flooding more frequently today.”

### 3.1.2 Environmental heterogeneity

In both the lower Rufiji and Kilombero Valleys, river dynamics have created a very complex environment that no hydraulic planning has

come to homogenize. The relative technical and economic performance of these two agrarian systems, and in particular the income generated by the families living there, is based on the skillful farming of this complex and relatively wild environment.

3.1.2.1 *In the lower Rufiji Valley*

This valley has been shaped by the flooding of the Rufiji River for thousands of years. The

present valley and its flood plain are bordered to the north and south by ancient fluvial terraces whose banks dominate the flood plain by one or two tens of meters (Fig. 3.7).

The following different landscape units can be identified:

- The largest, but least valued by farmers, are the ancient fluvial terraces, particularly the one on the left bank (to the north, on the right side of Fig. 3.7). The villages resulting

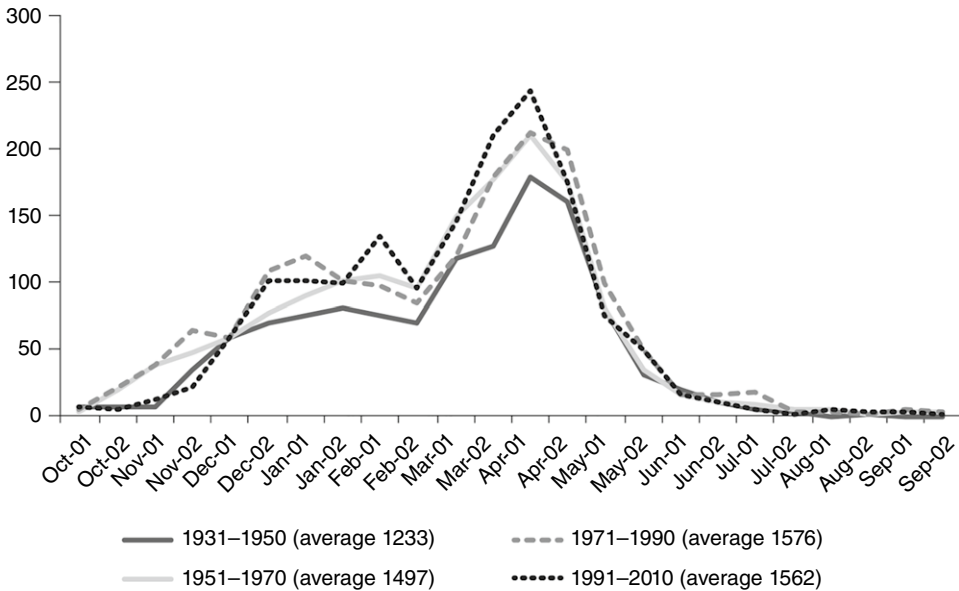


Fig. 3.6. Evolution of bimonthly rainfall volumes (1930–2010) by 20-year period. (From: climate data sheets from the Catholic Mission of fakara and the KATRIN research center; graph: Le Clerc, 2015.)

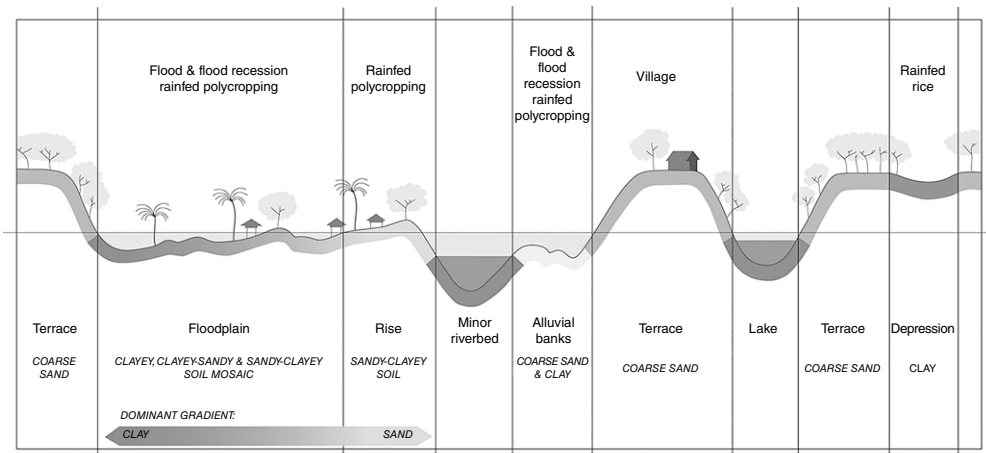


Fig. 3.7. Transect of the Rufiji Valley. (By Jean-Luc Paul.)

from the Ujamaa period villagization (1967–1968) are found here, lined up along the single path that runs along the river. This vast unit is heterogeneous. It is dominated by sandy soils (probably developed on ancient alluvium) and a *miombo*-type tree formation (open forest) exploited by herders (recently arrived and still few in number) and rare hunters. For the villagers, this area is the only source of firewood and timber (carpentry, half-timbering, dugout canoes, pestles, mortars, and furniture). In some places, it includes basins of a few hectares with more clayey soils (*njacha*). These were put into cultivation on the locals' initiative after villagization and are now much less intensively occupied. Villagers criticize them for being able to grow only one crop, rainfed rice flooded by runoff water, in the long rainy season. Moreover, the basins "perched" on ancient fluvial terraces (Fig. 3.7) are not fertilized by the river's flooding. The risk to agricultural production in this area is therefore very high, much higher than in other areas where, as we shall see, two main crops (rice and corn) and three cropping seasons can be combined.

- Lakes occupy fossil riverbeds carved into these terraces. The weakness of their watershed's size makes their episodic or regular recharge by flooding essential (Hamerlynck *et al.*, 2010; Duvail *et al.*, 2014). The lakes make up a unique unit, mostly dedicated to fishing, although the sill separating them from the river can be cultivated in small areas with rainfed crops (corn), during flooding (rice) or flood recession (corn).
- Sandbanks (*tingi/matingi*) occupy the concavities of the meanders of the minor riverbed. They are regularly remodeled by the flood (Fig. 3.7). Although they often have comparable forms (in spindles parallel to the river's main course), they differ in their surface area, height (more or less rounded in shape), age, and therefore in the vegetation that covers them. Exclusively sandy and without vegetation in appearance, they are gradually colonized by herbaceous plant cover. Thus, a reedbed is formed, which, during the flood, slows down the flow and favors the deposit of fine particles carried by the river. Some villagers regularly

visit these reedbeds and when they judge that the accumulation is sufficient (at least 30 cm), they decide to cultivate them. Within the same sandbank, especially if large enough, topographical variations create an edaphic patchwork. The very low, clayey areas that are most exposed to flooding are reserved for flood recession corn. The low, clayey areas are suitable for rice cultivation, but corn can be grown in these areas during the short rainy season. The intermediate micro-altitude zones, sheltered from mid-range water levels, are intended for corn cultivation in the short and long rainy seasons. On the bulging tops of some sandbanks, very sandy but almost always sheltered from flooding, long rainy season corn is grown. Here, the presence of mango, cashew, or banana trees testifies to the very low occurrence of flooding; the villagers will therefore build their field hut here (*ndungu/madungu*).

- The river's minor bed is separated from the flood plain by a levee, which remains safe from flooding, except in the case of exceptional floods such as in 1998 during a pronounced El Niño episode. The levee and the sloping bank that connects it to the flood plain are planted with mango and cashew trees (Fig. 3.7). Formerly preferred habitation sites before villagization, these places have been recently reinvested. The soil is rather sandy and especially suitable for sesame cultivation, and sometimes cassava and corn.
- Behind the levee is the flood plain. When the flood is sufficient—when the flow reaches at least 2500 m<sup>3</sup>/s (Duvail *et al.*, 2014)—the water enters it through a few collapses of the levee and flows through a complex network of channels and marshes and then joins the river downstream (Fig. 3.7). This area is conducive to the sedimentation of the finest particles (the water generally stagnates or flows very slowly) characterized by its much more clayey (and silty) soils and seasonal flooding, which favors rice cultivation. The general trend is that as the elevation decreases away from the levee, the soils become more and more clayey. The more clayey temporary marshes are the site of flooded rice cultivation par excellence.



Flooded areas with lighter soils can support an early rainy season corn planting followed by a flooded rice cycle and eventually a flood recession corn or cotton crop. Where areas have been flooded, corn or sesame can be planted at the beginning of the main rainy season. Finally, the flood plain is an important fishing spot but fishing here is very seasonal.

Despite the fact that this flood plain accumulates the risks associated with flooding and rainy season hazards, the space seems to have long attracted farmers. The lower Rufiji Valley was even known for a long time for its cereal surplus (Hamerlynck *et al.*, 2010). In contrast, the vast spaces of the ancient fluvial terraces on either side, sheltered from flooding, do not seem to have attracted farmers in the long term. Although locally provided with clayey areas that are a priori suitable for rice cultivation, farmers are not able to maintain the soil's fertility, as they have no means of obtaining synthetic fertilizers. Since the time of villagization, several of these areas have been successively cultivated (10–15 years) and then abandoned.

### 3.1.2.2 In Kilombero

The Kilombero Valley has a different cross-sectional profile. In contrast to the lower Rufiji Valley, the flood plain is not delimited by ancient fluvial terraces with a clear slope. On the other hand, the Kilombero depression is a graben

framed by strong reliefs, and its cross-sectional profile is “disturbed” by the presence of alluvial fans. These are formed by the Kilombero's tributaries, both on the left and right banks, and occupy part of the flood plain of the Kilombero itself (Fig. 3.8). The river's water level thus concerns, from a certain level of flooding, not only the flood plain of the Kilombero *stricto-sensu* but also the downstream part of these alluvial fans, this downstream part being subject, on the other hand, to the flooding of the tributary itself (Fig. 3.9). These alluvial fans have levees on both sides of the tributary that makes them up, or even fragments of levees that are evidence of the tributary's former passages (Jatzold and Baum, 1968).

The main landscape units are therefore arranged, on the one hand, according to distance from the river (along a toposequence perpendicular to the valley axis) and, on the other hand, according to position on the alluvial fan. The result is the different landscape units described below, starting from the lowest and most permanently flooded units up to the units that are always unflooded:

- Areas that are flooded each year by the Kilombero River and are permanently covered with a thick layer of water. This vast area, fishermen's domain during the flood, is dominated by a grassy formation on both sides of the river's minor bed (with *Phragmites mauritianus*, *Pennisetum purpureum*, *Megathyrsus maximus*, *Hyparrhenia sp.*)

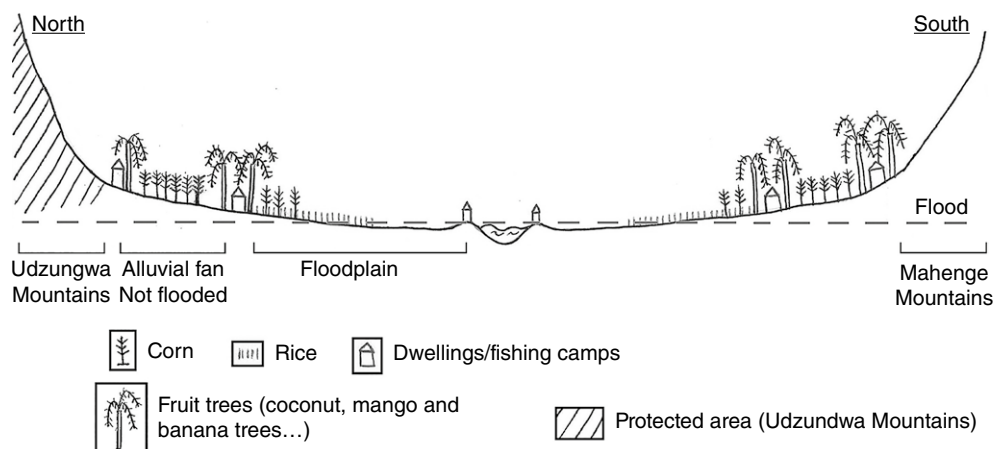
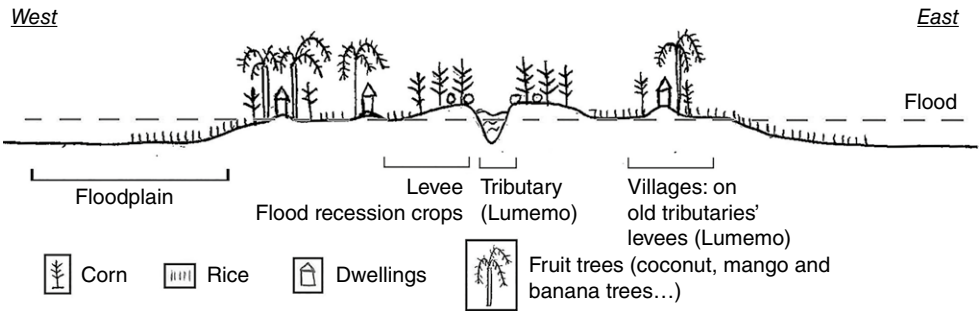


Fig. 3.8. Wide profile of the Kilombero Valley at Ifakara. (From: Le Clerc, 2015, from Jatzold and Baum, 1968.)



**Fig. 3.9.** East-west profile of the Ifakara alluvial fan. (From: Le Clerc, 2015, from Jatzold and Baum, 1968.)

and appears very heterogeneous as soon as the flood recedes: it includes (i) small sandy areas, in a high position and corresponding to former levees' remains (some small islands even have mango trees, coconut trees, and a fishing camp); (ii) less sandy areas, a little lower but still relatively high, that emerged quite quickly as the flood receded (some fields are then cleared and corn is direct drilled in seed holes); and (iii) other lower areas, corresponding to channels or basins, more clayey and from which the flood recedes last. The ridges of the previous year's crops are then visible; some of them will be recultivated.

- Grassy plains regularly flooded by the Kilombero but with less water, no trees, and suitable for rice cultivation in a normal year (one rainy season cycle), with flooding usually occurring during the rice boot stage. Between cropping cycles, these areas are covered with low vegetation, the dominant species being *Cyperus distans*, one of rice's main weeds.
- As one moves away from the river, the vegetation gradually reveals a few scattered trees, generally located on mounds corresponding to former termite mounds. Here, too, the flooding, although a little less pronounced, deposits its share of alluvium each year, ensuring the annual renewal of the soil's fertility. This landscape unit merges with the parts of the alluvial fans closest to the Kilombero River. Away from the alluvial fans, this unit is connected to the piedmont plain by large areas of very low slope, rarely flooded (or only for a short time and with a thin layer of water), and dotted with trees.

- There are areas sometimes flooded by the Kilombero's tributaries but not by the Kilombero itself, at least in a normal year (although, again, the lines are rather blurred). These alluvial soils are considered the most fertile in the region. The tributary's proximity, however, implies a very high risk of overflow and flooding in March–April. It is on this land that flood recession cultivation (in the dry season) is possible. Two cropping cycles per year can be carried out there: either two successive cycles of corn (rainfed in December–April and flood recession in June–October) or one cycle of rainfed corn followed by flood recession market gardening (eggplant, okra, squash, cucumber, watermelon).
- The levees (current and former) of the Kilombero tributaries are favored habitat sites, planted with various fruit trees (coconut, oil palm, mango, etc.).
- Finally, the “high” part of the alluvial fans, never flooded, with rather sandy soils, is the junction (break in slope) with the steep slopes of the Kilombero Valley hillsides, itself a very heterogeneous area. Only rainfed corn or sesame cultivation is practiced here.

## 3.2 Risk Management at the Field Level: Intercropping, Risk Anticipation, and Recovery

### 3.2.1 The example of the lower Rufiji Valley

In the Rufiji, risk management at the field level has at least two particularities. On the one hand,

the dual dependence of cropping systems on rainfall and flooding implies an accumulation of hazards, particularly with regard to rice cultivation. On the other hand, due to the proximity of the immense Selous reserve, the presence of wild macrofauna in the cultivated area is very strong. Faced with these two particularities, the populations of the Rufiji flood plain have long developed specific strategies. However, recent climatic changes are disrupting their effectiveness. For the sake of clarity, we will first describe these long-standing anti-randomization strategies and then analyze how villagers are responding to ongoing changes.

Traditionally, villagers planted short-season corn as soon as the first rains permitted it. Only the vagaries of rainfall affected the crop. Once this short-season corn was harvested, the cropping calendar depended on the area concerned. In flood-prone areas, rice was planted, a crop subject to the dual hydro-climatic hazard (a flood that is poorly synchronized with the rains damages the crop, either by submersion or, on the contrary, by water stress). In areas sheltered from average flooding, a crop of corn or sesame was planted during the long rainy season. In intermediate areas, rice and corn were combined, with the bet being that, depending on that year's particular conditions, one would benefit from the harvest of one crop or the other. Finally, when the floods receded, flood recession corn was planted or, until the 1960s, cotton. By simplifying the cropping calendar to just the main crops (rice and corn), the farmer had the option of four planting periods in the year, as shown in the following diagram (Fig. 3.10):

From a risk management point of view, this staggering over time counterbalanced the restrictions on the dispersion of fields within the different agroecological zones. Indeed, this dispersion is limited by the need for a quasi-continuous

presence in the field to protect the crop from the depredations of wildlife during its entire cycle. The omnipresence of field huts on stilts (*madungu*) in the landscape bears witness to this.

### 3.2.1.1 *The strategy of expanding corn-rice association as an anti-random response to climate change*

With the reduction of the short rainy season and the corresponding decrease in rainfall, corn is now planted much later. This leads to a telescoping of the two crops' cycles, and rice is thus interplanted with the unharvested corn. The corn/rice succession has thus become a crop "succession/association" in that the two cycles overlap to a large extent. As a first consequence, although farmers are now opting for shorter-cycle varieties, corn is exposed to flooding (see Photo 3.1). Thus, during the 2013–2014 season, many fields had to be harvested in a hurry, when the water had already risen. A second consequence is that planting rice within the cornfield is more laborious than in an already harvested field.

In addition, where flooding was once considered almost certain, it has become random. As a result, farmers have extended the strategy of combining rainy-season corn with rice to more fields. Here, the rice is sown 1 month after the corn. The two crops grow together in the rainy season. Depending on the year's hydro-climatic conditions, it is hoped that one or the other will provide a significant harvest. Of course, if there is insufficient rainfall and no flooding, or if the flooding is too early and too severe, both crops will be destroyed.

Finally, since the fields are not flat, *staggered* sowing of corn and rice, from the lower parts of the field to the upper parts (the differences in level being limited to a few tens of centimeters),

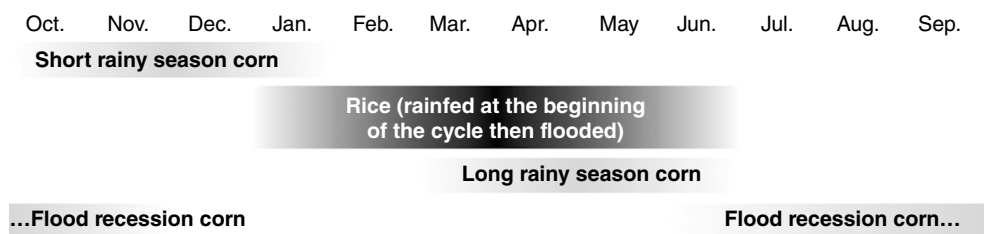


Fig. 3.10. Western Rufiji cropping calendar simplified to two main crops. (Courtesy of J.L. Paul.)

constitutes an additional means of increasing the chances of harvesting something, even in the most unfavorable rain and flood conditions.

The 2013–2014 season is a good example of a year in which the deleterious effects of two main hazards combined: an unfavorable rainy season (late arrival of the rains) and an exceptionally high flood. As the rains started very late that year, the planting of corn was itself very late, even though the flooding was greater and earlier than usual. Many cornfields were drowned before the grain matured, while others were harvested in 80 cm or 1 m of water before the flood reached the cobs. In this particularly unfavorable configuration, the late planting of rice may have led to its complete submergence and destruction when the flood suddenly arrived.

### 3.2.1.2 *Catch-up tactics as a response to increased hazards due to climate change*

Corn/rice association-succession is also practiced on the sandbank meanders of the minor riverbed (Fig. 3.7). The devastating flood of 2014 also provides a prime opportunity to observe both the considerable risks faced by farmers and the efforts made to limit their scope. That year, almost all of the “short rainy season” corn grown on the sandbanks was submerged by the flood, which also destroyed banana trees, sugarcane, and other minor crops, while the rice crop suffered significant damage due to early submergence.

Under these conditions, the traditional response is to plant a flood recession corn crop. However, this is a *medium-term* catch-up, as the first harvests are only possible from September onward. In order to avoid a period of scarcity, the only possible *short-term* recovery here was based on what remained of the rice fields. At the beginning of May, only the rice plants sown on the slightly higher parts of the fields, the bulging part of the sandbanks, were still emerging. From then on, it was still possible to partially compensate for the losses by taking seedlings from the fields that had been spared by the flood and transplanting them, when the floodwaters receded, into the lower parts where the rice had been prematurely drowned (see Photos 3.2 and 3.3). This transplanting technique, which is usually used marginally to increase the area cultivated, has a special nature here. At the cost of

considerable additional work, it allows for a certain catching up of the agricultural season and a notable reduction in the risk of scarcity.

Thus, the cultivation methods of these flood-prone areas—cultivable sandbanks and flood plains—reveal a permanent concern for farmers to limit the risks inherent in the double hazard of rainfall and flooding. Taking advantage of the environment’s subplot heterogeneity, combining successions and associations of crops with diverse characteristics, and maximizing the extension of the cropping calendar make it possible to create a diversity of agronomic situations, each corresponding to the anticipation of a particular hydro-climatic scenario. However, these strategies often prove insufficient, as was the case during the 2013–2014 season, and remedial techniques are then mobilized. In all cases, villagers are regularly called upon to make tactical decisions to adapt or even change their initial strategy.

This wise agriculture, which succeeds in making the most of an environment with little human intervention, has aroused the interest of several authors. It has been described as a *Risk Management System* by A. Sandberg (2004). In reference to this author, Hamerlynck *et al.* write, “The Rufiji flood plain farmers have come to grips with the interplay between short rains crops, long rains crops, floods and recession agriculture and the subtle use of the topographical variability, which defines the nature of the soils and their flooding frequency” (Hamerlynck *et al.*, 2010, p. 224).

## 3.2.2 In Kilombero

The Kilombero Valley and its potential for rice cultivation was the focus of early attention by the colonialists, and later by independent Tanzania’s agricultural extension services, and this led to greater integration with commercial trade and the development of tractor and chemical inputs. This is why it is necessary to go back far enough in history to find, in conversation with elderly farmers, cultivation practices that closely resemble those seen in the lower Rufiji Valley.

Because the rainy season here is shorter (*above*), there has never been a true corn/rice succession as in the lower Rufiji Valley. In the past, rice was sown “at Christmas rains,” that is,

the first heavy rains of December, with the rice being broadcast sown into the corn planted a few weeks earlier.<sup>2</sup> At that time (1950–1970 in Fig. 3.6), the rainy season began a little earlier and conditions were considered more favorable for agriculture. Corn was planted early and harvested well before rice, shortening the hunger gap. The corn-rice association was thus a way of managing the combined effects of the dual hazards of rainfall and flooding.

Our 2015 interviews in this region also show how the joint use of different rice varieties limited the risks involved.<sup>3</sup> The farmer subdivided his land into several plots on which different varieties were sown,<sup>4</sup> making it possible to limit the risks from various sources (climate, flooding, diseases). These varieties were distinguished by:

- A variable cycle length, allowing for adaptation to rainfall and flood fluctuations.
- Late varieties harvested in June, with earlier varieties harvested in March or April. The latter were not very popular, but they were used to get through the hunger gap. They have a distinctive name, grouped under the name “*Msonga*” (*Msonga Meli*, *Msonga Useneguse*).
- “Denser” varieties, intended for beer production.
- Variable resistance to diseases.

In addition to the flexibility allowed by the combination of several varieties, early or late, the harvesting techniques and culinary methods of preparing rice also increased the possibilities of staggering harvests and therefore consumption<sup>5</sup>: daily harvesting of the first panicles that have reached maturity for immediate consumption; harvesting before maturity, at the milky stage and consumption in the form of “*pepeta*” (the grains at the milky stage, unshelled, are fire-roasted and then crushed with a mortar); harvesting just before maturity (“*mchopeko*” rice: the grains are boiled in water and then sun-dried).

Finally, in the flood plain, it was sometimes possible to harvest rice regrowth on the lowest fields in very wet years: the grains that fell at harvest and germinated on the still wet soil allowed for a small complementary harvest. If the flooding was too great, the low yields of the first harvest were then partly compensated by this second harvest (Jatzold and Baum, 1968).

Older farmers unanimously state that the harvests in those days were much better than they are today: two to three acres of crops could feed a family all year long. The granary was never empty or only was a short time before the new harvest.

But these old practices were to be greatly modified, starting in the 1950s, by the emergence of larger, “commercial” rice or cotton farms, 10–20 acres (4–8 ha). The colonial government’s aim was to encourage the development of “avant-garde” farmers through easier access to motorization and inputs, in the hope of pulling up neighboring farmers, by transmitting knowledge “over the hedge” (Coulson, 1982).

### 3.3 Risk Management at the Production System Level: Dispersion, Complementarity, and Risk Mitigation

#### 3.3.1 In the lower Rufiji Valley

At the time of Ujamaa villagization (1967–1968 and 1973–1974), the inhabitants of the Rufiji had to leave their hamlets on the flood plain and gather in villages located on the fluvial terraces. Here, the rainfed agriculture recommended by state services quickly proved unsuitable, and villagers invented a new cropping system, flooded rice cultivation in the terraces’ clay depressions (Fig. 3.7). However, depending solely on rainfall, with a range of crops almost entirely limited to rice, and a highly constrained cropping calendar, the villagers found themselves in an increasingly precarious situation. Thus, in the mid-1980s, as soon as government pressure eased, most farmers moved to the flood plain and to the sandbanks of the river. The fertility was better there and above all the range of environmental conditions was greater. In spite of the hazards, and in particular the risk of flooding, the “sand” banks and the areas where the floodwaters spread had not lost any of their attractiveness.

It is known that the combination of different activities by the same family is a guarantee of reduced vulnerability. In the western part of the Rufiji District, this diversification is based primarily on the combination of fishing and farming. Fishing, a male activity, makes up an important part of the income. It provides at least

40% of food needs (by allowing the purchase of corn flour during the hunger gap, cooking oil, salt, etc.). It also covers the vast majority of non-food monetary expenditures (Paul *et al.*, 2012). Agriculture, a mixed activity mainly conducted by women, is essentially food producing, although surplus rice and corn can be sold, and sesame and cashew trees are grown for sale. The first guarantee of security is therefore carrying out fishing and farming activities in parallel, which presupposes the balanced presence of adult men and women in the household. Single women (widowhood, divorce) are always in precarious situations.

But diversification strategies also concern agriculture itself. Access to different landscape “facets” allows, first and foremost, greater food security, but it also makes it possible to obtain cash income that is complementary to that of fishing. However, several factors stand in the way of this access. The first is, due to the proximity of the Selous Reserve, the strong presence of macrofauna (warthogs, baboons, antelopes, passerines, and even hippopotami and elephants). During the entire cultivation cycle, from sowing to harvesting, day and night surveillance of the field is essential. This explains the scattering of the landscape with field huts on stilts (*madungu*). The wife and young children live there during the cultivation season. In addition, the cultivation of a field is never an isolated act. To keep unwanted wildlife away, one always makes sure that the neighborhood itself will be cultivated by relatives, associates, or friends. Thus, if for a given cropping season, a household tries to cultivate several terroirs (sandbanks, flood plains, or clay depressions of fluvial terraces), the household will favor the surveillance of one of them and expose the other fields to a high risk of wildlife depredation. On the other hand, the change of terroir from one season to the next, during the same year, is frequent and does not lead to this risk exposure.

The second factor limiting access to diversified terroirs is that some of them are small. While a significant land reserve still exists in the flood plain, the levee and its sloping bank are small. However, it is only here that cashew cultivation is possible,<sup>6</sup> the only cash crop of any importance since the near disappearance of cotton after villagization. Villagers who have fields on the levee generally have direct access to the flood

plain to the south and, in some places, to the minor riverbed’s sandbanks to the north. The sandbanks also have a limited extension. Their main characteristic is high flood exposure; this is an advantage during a flood too small in magnitude to completely penetrate the flood plain. It is also a disadvantage in the case of a large and rapid flood. Households forced to cultivate only this land are therefore very vulnerable, while those who also cultivate another land find it a very useful complement.

Agricultural diversification strategies (in addition to the exploitation of subplot diversity mentioned in section 3.2.1) are therefore based on the successive rather than synchronous development of different facets during the year. The question of access to the different terroirs is therefore crucial. From a legal point of view, access to the flood plain is relatively easy, as long as it is not monopolized by industrial agriculture projects. However, the households’ demographic structure sometimes opposes this access. Elderly households, single-parent families, families whose husbands are almost exclusively involved in fishing, and small families with no strong family ties are not very mobile. They are often forced to limit themselves to farming land that is easily accessible from the village, namely the clay depressions of the terraces and the river’s sandbanks. Their situation is more precarious. Finally, a few families who arrived during the villagization process and who have a rainfed agricultural tradition essentially exploit the levee’s non-floodable sloping bank. Their dependence on rainfall conditions also places them in a precarious situation. As an example, the [Table 3.1](#) characterizes some agricultural situations based on Tewa’s work (2014); this table is not exhaustive.

### 3.3.2 In the Kilombero Valley

In this region, the villagization of the 1970s did not prevent access to diverse ecosystems and thus did not have deleterious effects as in the lower Rufiji Valley (*above*) or the Iringa region (Chapter 2, this volume). Although settlement in the Kilombero Valley was originally dispersed, with families settled on small mounds protected from flooding, there had been several moves to cluster dwellings on the levees of the alluvial

**Table 3.1.** Characterization of some agricultural situations in Western Rufiji District. From Tewa (2014).

Access to the terroirs	Characterization	Agricultural income per worker per year (Euros, 2014)
Levee and its sloping bank Flood plain Possibly sandbanks	Thanks to the diversification possibilities: – Saturation of the work calendar – Good labor productivity – Risk reduction	800–900
Sandbanks only	High exposure to hydrological risk Diversification limited to subplot strategies	250
Levee and its sloping bank	High exposure to climate risk Diversification limited to rainfed crops Possibility of cashew tree cultivation	500
Clay depressions Sandbanks (in flood recession)	High exposure to climate risk Dependence on flooding for flood recession crops	500

fans in the past, so that settlement was already fairly well clustered.

In this region, this period also corresponds to the construction of the Dar es Salaam-Lusaka railroad. At the end of construction, groups of workers who had worked on the construction site settled permanently in the region, participating in its demographic growth, the emergence of new villages along the railroad, and the establishment of a class of landless workers. This last point is not without importance for the subsequent evolution of the region's production systems.

### 3.3.2.1 *The importance of the corn/rice combination at the farm level*

Until the 1960s, corn was only planted in association with rice at low density. Its function was to bridge the hunger gap “while waiting for the rice harvest” (*supra*). In the following decades, corn became more important and was grown on its own fields. Indeed, as rice was sown later and later (*below*), and as the use of tractors for soil preparation became more widespread, it became more difficult to continue with the crop combination (with earlier sowing of corn, as before). This made it easier to plant corn on separate fields, especially since the possible lengthening of the hunger gap, linked to the delay in planting rice, reinforced corn's role as a hunger crop. Gradually, all farmers began to grow rice and corn on separate fields, with corn increasingly grown on the still-excavated fields located higher up in the valley's toposequence. This development of corn

cultivation was also encouraged by the National Maize Plan, promoted from the mid-1970s onward (Chapter 2, this volume), although the Kilombero Valley was not one of the main target areas.

Recent history is thus marked by the decline of corn-rice association in favor of cultivation on separate fields within the farm. Rice occupies most of the land, while one or two acres are reserved for corn, mainly for self-consumption. In the farmer's minds, the main crop is rice, with corn remaining for the hunger gap season (March–June).

### 3.3.2.2 *Dispersing rice fields to reduce risk*

Given high rainfall variability, particularly at the beginning of the rainy season, and the unpredictability of both the water level in March/April and the flood's duration, cultivating several sites makes it possible, as in the lower Rufiji Valley, to divide risk and ensure a minimum production level each year. Farmers therefore systematically try to have several rice fields located on sites with different exposure to flooding. This strategy is, however, limited by the farmer's ability to finance the crop year (*below*) and made increasingly difficult to implement with increased land pressure, the relative scarcity of land, and its increased distance from dwellings. As a result, young farmers who have recently settled down sometimes have to make do with a single field, exposing themselves more directly to the impact of annual fluctuations in climate and flooding.

### 3.4 Further Integration into Market Exchanges and “Agricultural Modernization” in the Kilombero Valley: Toward New Hazards?

#### 3.4.1 Integration with market exchanges and reduction of varietal diversity

The joint use of early and late varieties and the staggering of each cultivation operation (sowing, weeding, harvesting) had a threefold objective: avoiding excessive workload peaks, adapting to fluctuating climatic conditions and the unpredictable level of flooding, and thus shortening the hunger gap period as much as possible.

Today, some farmers still mention this staggering of sowing from mid-December to early February, but entry into the market economy has led to a significant reduction in agrobiodiversity. Indeed, as Kilombero has become an important rice-growing area, the varieties chosen by farmers are in fact those that are most valuable on the market and for which Kilombero is known: highly aromatic but long-cycle varieties. The length of the cultivation cycles therefore tends to be homogenized around 5–6 months. Thus, the range of cultivated varieties is now reduced to about ten. A poor harvest can therefore no longer be compensated for by using short-cycle varieties to limit the hunger gap. The importance of corn and its development during the 1980s is therefore easy to understand.

However, farmers remain attached to their traditional varieties, especially since they remain highly adapted to the conditions of the valley and are still highly prized in urban markets.<sup>7</sup> Although sensitive to lodging, these high-straw varieties (1 m high) allow better adaptation to subplot heterogeneity and the changing height of the water table. Their diversity also makes it possible to spread out workload peaks a little more.

##### 3.4.1.1 *The difficult financing of the agricultural year*

Today, farmers’ cash flow is often partly devoted to covering rice cultivation costs: almost all farmers use a tractor for plowing and harrowing. Even on small farms, the farmer always uses the tractor in December for pre-planting

plowing, and then for post-sowing harrowing. Each of these operations is done at a cost of TZS 40,000 per acre. In addition, larger farms will need to pay for the day workers required for manual weeding (or purchase of herbicide), harvesting, and, if necessary, transport. As far as inputs are concerned, only one herbicide is commonly used for rice, namely 2,4D (2,4-dichlorophenoxyacetic acid).<sup>8</sup>

In the absence of favorable access to credit, it is the sale of paddy that covers the season’s costs. Therefore, the previous year’s paddy stock determines the following area planted, limited of course by the family labor force’s maximum capacity (generally set at 2 acres/worker). A year with a good harvest and high selling prices allows a farmer to cultivate all their fields the following year. A poor harvest (exceptional flood), unforeseen expenses (e.g. illness), or a drop in prices will directly limit the capacity to plant. Thus, family farms’ cultivated area fluctuates from year to year according to the combined fluctuations of climate, prices, and family contingencies.

##### 3.4.1.2 *Shifting the sowing date: climatic disruption or increased market dependence?*

Today, producers all sow rice in January, whereas older people systematically mention sowing in December “at the time of the first rains” (*supra*). Is this delay in sowing rice solely the consequence of the rains’ general delay over the last few decades, or is it also a consequence of the increased use of inputs and tractor services in the context of deficient financing of the agricultural year?

Since crop advances are usually financed by selling the previous year’s paddy crop as needed, attempts are made to sell paddy at the best price possible. Since December is a period of rising prices, farmers postpone the sale of their paddy as much as possible, even if it means delaying the sowing of rice too long and exposing it too early to flooding. The search for this difficult balance between the best paddy selling price and the sowing date helps explain why rice is now sown in January, much later than in the 1960s or 1970s, to be harvested from May to July.

Thus, it seems that the delay in sowing toward January is as much the consequence of a delay in rainfall, as often presented by valley farmers, as it is an effect of the difficulties in



financing the crop, particularly the tractor.<sup>9</sup> This example illustrates the difficulties encountered when discussing climate change and its consequences with farmers, and the precautions to be taken in this regard: “talking about the climate without talking about it” (see “Introduction”) and being careful to place the possible consequences of a lasting change in the climate in the context of those resulting from changes of another nature.

### 3.4.2 Increased socioeconomic differentiation

The region’s increasing monetization, the decline in the relative prices of cereals and labor (linked in particular to the implementation of the structural adjustment plan), increasing access to tractors for soil tilling, and the presence of a salaried labor force (day laborers) are all factors that have favored an increase in cultivated areas and production for some families. But the widening of the cultivated area relies on a daily paid labor force with limited access to land.

Moreover, once corn and rice were grown on separate fields, and with an almost synchronous cropping calendar, the two crops became competitors for labor. Combining them beyond an area of a few acres results in significant labor peaks. As a result, growers now almost systematically use off-farm labor force for weeding and harvesting.<sup>10</sup> Access to a low-cost labor force then allows a category of farmers—those better-off—to expand the cultivated area, especially after the arrival of private contractors offering tractor plowing services, which also facilitated this expansion. Very quickly, from the 1990s, families with the means to expand their areas were able to produce about four times their annual consumption (Kato, 2007).

The economic results of the main types of farms encountered in the region were estimated by Le Clerc (2015). By way of example, we will describe the following cases:

- The most common production system in the region is the one implemented by two working family farms cultivating between 2.5 and 6 acres (1–2.5 ha). The land is divided between flooded rice in the valley lowlands (clay zones) and rainy-season corn on the alluvial fan’s flooded lands.

These farms, which are often based on the old levees (with a garden orchard), usually fish almost daily, which provides a significant part of the income. While corn is planted on one to two acres for self-consumption, without inputs or outside labor, the rest of the area is planted with rice (2–5 acres), using the tractor for plowing and harrowing. The anti-dicotyledons herbicide 2,4D is often used, but chemical fertilization is not, as it is considered too expensive. As with all small-scale family farms, rice is sold as the year progresses. The rice stock is usually exhausted by January, with most of the production sold before prices reach their peak. Around the houses, there are usually coconut, banana, and oil palm trees, and a small vegetable garden, which provide a regular income throughout the year. The income generated by this type of farm (including self-consumption) is very low, in the order of 220–370 euros/laborer/year.<sup>11</sup> Extreme weather events are therefore a permanent threat and a brake on these small family farms’ economic development insofar as, without any alternative financing, their production capacities are based solely on the previous year’s performance.

- Farmers with access to fields close to the river’s minor bed and suitable for early dry-season market gardening, once the flood has receded, fare better. Although these fields are very fertile and cannot be used for rice in the rainy season, the water level being too high in April, they are very suitable for off-season market gardening. The water is brought thanks to a bucket or watering can. In addition to the 2.5 and 4 acres (1–1.6 ha) of flooded rice in the clay areas and 1–2 acres of rainy season corn, vegetables are grown on 0.5 acres (this is the maximum allowed by the labor load required for hand watering). The financial resources from market gardening make it easier to call on off-farm labor force in a timely manner with the goal of more and higher quality production. The income generated can then reach the equivalent of 700–900 euros/laborer/year.
- There are also slightly larger farms, with 5–7 acres, 3–5 of which are flooded rice (4 t/ha) and two of which are corn (4.5 t/ha),

using chemical inputs and employing many day workers. Yields are higher and farm income exceeds 1300 euros/laborer/year.

- Finally, there are large motorized patronal farms (a secondhand tractor and a tractor driver) with a larger surface area, between 50 and 70 acres. With the exception of tillage, the entire crop management sequence is carried out manually by external workforce, with weed killer (2.4D), but without recourse to chemical fertilizers. Yields are therefore similar to those of the small family farm, and the annual value-added does not exceed 400 euros/ha. The tractor is mainly made profitable as a service provision to other farmers, as demand is very high in the Kilombero Valley.

### 3.5 Large-Scale Development Projects and “Intensive” Rice Cultivation: Reducing Hazard and Vulnerability?

#### 3.5.1 In the lower valley of the Rufiji River

Since the beginning of colonization, the lower Rufiji River Valley, like other regions with comparable characteristics, has been the object of ambitious planning projects based on the erection of large dams with the combined functions of electricity production, flood control, and irrigation of the downstream part of the valley (Duvail *et al.*, 2010). The recent arrival of new foreign investors and legislative changes facilitating their reception are now reviving these large projects, which are presented by their promoters as a privileged path toward adaptation to climate change (National Irrigation Master Plan, NIMP, 2002). By greatly reducing the risk of flooding through extensive artificialization of the environment, they would be able to substantially increase agricultural production while securing it in the long term. The massive creation of jobs for local populations and the consequent improvement of their standard of living are also put forward as benefits of such projects.

In Rufiji, about 20 investors, mostly foreign, are reportedly currently in the pipeline (Tewa, 2014). Specifically, in the study area, the project is expected to result in the creation of an irrigated

rice farm covering more than 8000 ha of flood plain. In order to provide investors with long-term land security, the State has previously asked village authorities to validate a zoning of the communal territory that distinguishes between the area currently under cultivation and a “land reserve.” It is this “land reserve” that the Tanzanian government intends to lease to national or foreign investors, if possible, with the agreement of the plenary village assembly (or otherwise in an authoritarian manner as authorized by law).

As we have written elsewhere (Cochet, 2014), most of the investment projects proposed in the countries of the South concern areas that benefit from conditions that are eminently favorable to agriculture (soil fertility, water resources, accessibility). Therefore, most often, those areas have long been occupied by agricultural societies characterized by a relatively high population density and labor-intensive production systems. Some of these characteristics are found in the lower Rufiji Valley, but also in several large African deltas where both agricultural and livestock activities are concentrated: the inland deltas of the Niger (Mali), Awash (Ethiopia), and Chari (Cameroon/Chad) and the Tana Delta (Kenya). The large-scale investments made by foreign public or private agents actually result in the substitution of pre-existing agrarian systems by new ones. Those investments are not a conquest of “virgin” land (i.e. unexploited land for which the opportunity cost of land, water resources, and labor would be zero), as it is often incorrectly stated. Real progress in terms of production, value-added, and job creation is therefore uncertain and must be analyzed on a case-by-case basis (*Ibidem*).

A thorough reflection on projects concerning the lower Rufiji Valley, in terms of economic evaluation, is not possible within the framework of this chapter, especially since the fieldwork carried out within the context of this research program was not oriented in this direction. However, the knowledge acquired on the dynamics of the agrarian system that would be affected by this type of project allows us to advance that the central problem with creating a large dam is the suppression of flooding. This would mean no more fishing, dried-up lakes, and the end of flooded and flood recession agriculture. In the case of the lower Rufiji Valley, however, we have

seen that families' agricultural income depends closely on their ability to combine different cropping systems that take advantage of the environment's different "facets." Among these different areas, the flood plain is the most sought after by farmers because of its greater potential, despite the risks involved. However, it is precisely this space that is today coveted by development projects and that risks completely eluding the region's inhabitants, or even becoming the scene of a massive eviction.

Despite compensation from the Tanzanian government (in what amount?)<sup>12</sup> and possible salaries distributed by the project (the number of which is generally greatly overestimated at the time of the project's announcement), such a project is likely to result in an increase in populations' vulnerability and precariousness, either by depriving them of access to one of the areas exploited or by reducing all possibilities of compensation and managing the environment's heterogeneity.

In addition, beyond these projects' often very high investment costs, they are supposed to generate a higher value-added per surface area unit than "traditional" production systems. It remains to be seen over time, as does the planned structures' capacity to withstand very large floods, the frequency and intensity of which, as we have seen, are likely to increase.

The paradox of such planning, whose objective is to reduce the risks incurred by climatic hazards, through artificializing and homogenizing the environment (in the hope of increasing yields and reducing their variability), is precisely that there is a high probability that they will increase populations' vulnerability.

### 3.5.2 In Kilombero

In order to facilitate foreign direct investment (FDI), SAGCOT was created in 2010 to develop agricultural production in a corridor linking Dar es Salaam to Zambia. In the form of a public-private partnership, SAGCOT is the first initiative in a series of corridors on which large-scale agricultural production development programs will be focused to "ensure the country's food security, reduce poverty, and increase resilience to climate change." In a now familiar pattern, it is proposed to initially promote the establishment

of large, capital-intensive, high-yielding farms, in the hope that this economic development will lead to easier access to inputs, credit, moto-mechanization services, markets, and training for the surrounding small farms, which would then see their yields increase.

Within the Kilombero "cluster," three sites have been identified for large-scale, privately owned farms, two of which, each with an area of approximately 5200 ha, would be for rice cultivation: the Ngalimila and Kihansi sites in the southwestern part of the valley (SAGCOT, 2012).

We will not address here the question of these spaces' current occupation by valley populations and the possible consequences, in terms of social eviction, of the implementation of these two projects. However, the analysis will focus on the support program that would be put in place to ensure that innovation would spread to small producers.

To address this question, we looked at rice company Kilombero Plantations Limited (KPL), which has been operating since 2008 near the town of Mngeta, in the southwestern part of the study area for this research program. KPL has a 5000 ha concession for 99 years. Since 2010, KPL, in partnership with USAID, has been implementing an agricultural extension program for farmers in the surrounding area aimed at increasing rice production through the use of selected seeds, inputs, and a specific crop management sequence.

We drew inspiration from the evaluation methods commonly used in the economic evaluation of projects. They are based on the measurement of a differential between the situation resulting from the project's implementation, on the one hand, and the situation that would have prevailed if the project had not been implemented (counterfactual or "without project" scenario), on the other. In the absence of a diagnosis of the pre-project situation in the KPL project's actual location, the agrarian system described in the preceding pages was chosen as the "reference situation." Insofar as this is a region close to the one concerned by the project, from a biophysical point of view (geomorphology, pedoclimatic and hydrological conditions), but also from a socio-economic perspective (population's origin and demographic density, cultivation and livestock techniques, access to markets, etc.), this choice

seems reasonable and likely to limit the biases inherent in this type of comparison.

KPL offers agricultural training in the System of Rice Intensification (SRI). This technical package includes selected short-strawed varieties (SARO5), row seeding, and fertilization (NPK and urea). Depending on the fields' topographical position, it is possible to use either direct drilling (e.g. rainfed rice in unflooded areas close to the mountains) or rice paddy fields with nurseries for flooded areas. After each training session, farmers leave with the necessary tools to implement this technical package at home, on a small area. In 5 years, more than 7400 farmers have benefited from this training.<sup>13</sup>

Interviews conducted by Le Clerc with farmers using this new technical package revealed the following observations:

- Fields cultivated with SRI produce significantly higher yields (up to 7 t/ha of paddy), and the income from the sale of paddy helps to repay the SRI loans. In addition, farmers who implement this crop management sequence on one of their fields also use synthetic fertilizers or pesticides on the other rice and corn fields on their farm, thus obtaining better yields. Thus, farmers who benefit from this program do not limit their use of inputs to SRI fields.
- Yet, paradoxically, the adoption of the SRI technical package is very limited on any given farm. Indeed, small family farms apply this technical package to only one acre, while owner-managed farms apply it to a maximum of 20% of their land. The rest is cultivated according to the "usual" techniques.

Why do farmers devote such limited area to this new crop management sequence, even though it is effective in terms of yield increase? Several reasons can be given:

- Row seeding or, *a fortiori*, transplanting, requires far too much time to be generalized to all fields. For the farmers interviewed, the implementation of these practices results in a significant increase in labor and input costs that can only be done in small areas.
- The valley's traditional varieties sell much better and it is often difficult to sell the production from selected seeds that are not very aromatic (SARO5).

- This crop management sequence requires high financial resources per unit area (labor, inputs) and recourse to credit is unavoidable.
- On the other hand, although these systems provide at least partial protection against climatic hazards (especially for transplanted fields), the financial risk seems disproportionate and can make the farmer even more vulnerable in the case of crop failure. This is a crucial issue in Kilombero.

In the region studied, we saw that for a majority of farms, especially the smallest, the area actually cultivated depends on the previous year's harvest. It is thus conceivable that the overall budget for a year of SRI cultivation is so high that a poor harvest would be disastrous for households if all the available land were cultivated that way. Dedicating part of the land to the SRI system and the other part to the "traditional" system makes it possible to hope for a better harvest in a normal year, without incurring excessive costs. This is a way to increase income while limiting the risk of climatic hazards. Given the climate's great variability, farmers' ability to withstand a year of low yield seems to be at the heart of their reasoning concerning their cropping practices.

Here, as in many parts of the world, the number one objective for public authorities, companies, and the accompanying projects is always to increase yields, presented as an end in itself. However, for a family farm, the objective is not to achieve the best yields because such a strategy is always linked to high agronomic and economic risks. The first objective is to ensure an income that will allow the household to live and, if possible, to invest. Thus, the family farm is characterized by a permanent concern for limiting the risks of obtaining an income incompatible with the family's survival.

In the case of the program implemented by KPL, the crop management sequence that was popularized and supposed to increase resilience to climate change, in accordance with SAGCOT's recommendations, actually increases the risk incurred by farmers. It is this increased risk that is the main limitation to disseminating the crop management sequence.

Farmers' frequent use of the inputs provided by the project beyond the field covered by the recommended crop management sequence

is also instructive. It is often proof that farmers have a great need for the inputs offered to them, but not always for the techniques associated with them. It illustrates once again that the promotion of an overly rigid, one-size-fits-all technical package can be counterproductive. Indeed, a technique that is not adapted to farmers' constraints (e.g. row sowing, which requires too much work) is enough to block the entire dissemination process, and in particular the use of new inputs, unless they are "diverted" to other uses, which are considered more productive.

### 3.6 Conclusion

In the Kilombero and Rufiji flood plain valleys of southern Tanzania, the agrarian systems' performance and the income generated by households are based on the skillful exploitation of a complex and rather unartificial environment. Here, risk mitigation strategies cannot be assessed without a detailed knowledge of the environment's micro-heterogeneities and the practices implemented to take advantage of them, particularly at the field level. The combined corn/rice crop on the sandbanks and in the flood plain of the lower Rufiji Valley offers an eloquent example of this fine and evolving adaptation to rainfall and flooding hazards. Here, intercropping is not only a "strategy" for anticipating and reducing risk, which makes it possible to "not put all one's eggs in one basket," or a practice for limiting sanitary risks. It is also a means of adaptation and a path toward management that takes the characteristics of the beginning of the rainy season into account (date of the first significant rainfall, spacing of the first rains, rainfall volume, etc.).<sup>14</sup>

Other examples could illustrate this point. For example, Crane *et al.* (2011) describe the adaptation of practices at the cropping system level in a region of southern Mali: on very heterogeneous soils (sandy/clayey) and taking the rainfall hazard into account, farmers sow

sorghum and millet together in the same field. After plants have emerged and in view of the seasons' first rains and the soil moisture content, farmers keep only the sorghum plants if the season looks good, or on the contrary, only the millet plants, if the rains seem insufficient.

On the other hand, an approach in terms of production system (and activity system) allows us to understand how access to different ecosystems and the combination of different cropping systems and off-farm systems (such as fishing, in this case), limit risks, this time at the family level, by relying as much as possible on the complementarities offered by the range of activities accessible to farmers. The families in the best position, generating the highest income and better equipped to face the various hazards they are confronted with, are always those that can combine the greatest number of crops and extra-agricultural activities in a variety of spaces or landscapes. This combination is of course dependent on the availability of means of production (tools, livestock, inputs, etc.), labor, and market access conditions.

The hazard is not only climatic—far from it. The difficulties Kilombero Valley farmers encounter in financing their rice crop have shown us this. Here again, there are countless examples that could reinforce this point. In the case of the Masa-Bugudum villagers of northern Cameroon, Jean Wencélius (2016) demonstrates that difficulties in accessing production factors like seeds and plows (the inability to obtain them at the right time), the loss of a laborer on which one was counting (displacement, social obligations), or the morbidity and fatigue inherent to the hunger gap, all play a role in the failure to carry out certain cropping projects. These factors are much more important than the climatic hazards that farmers have ultimately learned to integrate into their strategies or to compensate for in one way or another. For them, climatic uncertainty is a certainty; the "real" hazards, those that are "unpredictable," come from elsewhere.

### Notes

<sup>1</sup> The exploitation of such an unpublished series by non-specialists is delicate and would deserve some preliminary tests (e.g. the Pettitt test to check the series' homogeneity, as advised by G. Beltrando, personal communication January 13, 2016).

<sup>2</sup> Small vegetable gardens occupied the raised mounds sheltered from the flood; squash, eggplant, okra, African eggplant, and cassava were grown.

<sup>3</sup> In Rufiji, about ten varieties of rice are used. They differ in cycle length (3–6 months), height of booting stage, organoleptic qualities, etc. It is known that with the current climatic changes, Rufiji farmers have abandoned long-cycle varieties in favor of medium- and short-cycle varieties. It is likely that in-depth historical investigations would reveal that here, as in the Kilombero Valley, the use of this range of varieties corresponded to anti-risk strategies.

<sup>4</sup> The first varietal inventories date from 1903: a German captain sent 26 cultivars to the colonial government to test their characteristics. It emerged from this study that a long local selection process had allowed the development of an important agroecological diversity (Stuhlmann, 1909).

<sup>5</sup> Similar harvesting and cooking techniques are found in the Rufiji.

<sup>6</sup> Further east, rainfall allows cashew cultivation on the fluvial terraces.

<sup>7</sup> Much more, for example, than the medium-sized and semi-aromatic varieties promoted by research centers, such as SARO5.

<sup>8</sup> Very few farmers use fertilizer except in low fertility areas, as flooding still plays a major role in the reproduction of fertility. Corn, intended for self-consumption (especially during the hunger gap), is generally cultivated by family labor and without inputs.

<sup>9</sup> In addition, the still insufficient tractor availability also plays a certain role in delayed sowing, especially since the fields are difficult to access. The tractor owner gives priority to the largest and best-placed fields.

<sup>10</sup> A harvest results in an overripe, more brittle rice, which sells for less at the huller.

<sup>11</sup> This is hardly more than in the base Rufiji Valley, where farmers have no access to tractors and use almost no “modern” inputs.

<sup>12</sup> As is the case in many regions of the world, eviction compensation is likely to be based on a significant underestimation of the value-added produced by farmers in these areas, an underestimation based on a lack of knowledge of local practices, as well as the failure to take into account associated crops and self-consumption when calculating income.

<sup>13</sup> According to the program manager at KPL in Mngeta, interviewed on May 15, 2015 by Le Clerc.

<sup>14</sup> We thus agree with Richard, who wrote about intercropping as a risk management practice: “They are looking for the combinatorial logic in intercropping where what matters to (farmers) is sequential adjustment to unpredictable conditions” (Richard, 1993, p. 67).

## References

- Cochet, H. (2014) Accaparements fonciers et grands projets agricoles privés: exclusions paysannes ou création d'emploi? In: Boussard, J.M., Cochet, H., Coste, J., Delevoeye, J.-P., Dumazert, P. et al. (sous la dir.) *Les Exclusions paysannes: Quels impacts sur le marché international du travail*. AFD, Conférences et Séminaires, Paris, France, pp. 53–62.
- Coulson, A. (1982) *Tanzania: A Political Economy*. Oxford University Press, Oxford, UK, 348 pp.
- Crane, T.A., Roncoli, C. and Hoogenboom, G. (2011) Adaptation to climate change and climate variability: the importance of understanding agriculture as performance. *NJAS—Wageningen Journal of Life Sciences* 57(2011), 179–185.
- Duvail, S. and Hamerlynck, O. (2007) The Rufiji River flood: plague or blessing? *International Journal of Biometeorology* 52(1), 33–42.
- Duvail, S., Médard, C. and Paul, J.-L. (2010) Les communautés locales face aux grands projets d'aménagement des zones humides côtières en Afrique de l'Est. *Politique Africaine* 117, 149–172.
- Duvail, S., Mwakalinga, A.B., Eijkelenburg, A., Hamerlynck, O., Kindinda, K. and Majule, A. (2014) Jointly thinking the post-dam future: exchange of local and scientific knowledge on the lakes of the Lower Rufiji, Tanzania. *Hydrological Sciences Journal* 59(3–4), 713–730.
- Hamerlynck, O., Duvail, S., Hoag, H., Yanda, P. and Paul, J.-L. (2010) The large-scale irrigation potential of the lower Rufiji floodplain: reality or persistent myth? In: Calas, B. and Mumma Martinon, C.A. (eds) *Shared Waters, Shared opportunities: Hydropolitics in East Africa*. IFRA/Mkuki Na Nyota, Nairobi, Kenya, pp. 219–234.
- Jatzold, R. and Baum, E. (1968) *The Kilombero Valley, Characteristic Features of Economic Geography of a Semihumid East African Floodplain and Its Margins*. Weltforum Verlag Munchen, Dillingen, Germany, 154 pp.
- Kato, F. (2007) Development of a major rice cultivation area in the Kilombero valley, Tanzania. *African Study Monographs* Suppl. 36, 3–18.

- 
- Kilembe, C., Thomas, T.S., Waithaka, M., Kyotalimye, M. and Tumbo, S. (2012) Tanzania. In: Waithaka, M., Nelson, G.C., Thomas, T.S. and Kyotalimye, M. (eds) *East African Agriculture and Climate Change. A Comprehensive Analysis*. IFPRI/CGIAR, Washington, DC, pp. 313–345.
- Le Clerc, P. (2015). Adaptation des agriculteurs d'une vallée inondable à l'aléa climatique, Diagnostic agro-économique de la vallée du Kilombero, Tanzanie. Mémoire de master Recherche «pays émergents et en développement», UFR Agriculture Comparée et Développement Agricole, AgroParisTech/AFD, Paris, 147 pp.
- National Irrigation Master Plan (NIMP) (2002) United Republic of Tanzania, (Ministry of Water and Irrigation, National Irrigation Commission), Dar Es Salaam.
- Paul, J.-L., Duvail, S. and Hamerlynck, O. (2012) Appropriation des ressources «naturelles» et criminalisation des communautés paysannes: le cas du Rufiji, Tanzanie. *Civilisations* 60(1), 143–175.
- Richard, P. (1993) Cultivation: knowledge or performance. In: Hobert, M. (ed.) *An Anthropological Critique of Development: The Growth of Ignorance*. Routledge, London, pp. 61–78.
- SAGCOT (2012) *Investment Partnership Program, Opportunities for Investors in the Rice Sector*. Slideshow Presentation, October 2012.
- Sandberg, A. (2004) Institutional challenges to the robustness of floodplain agricultural systems. In: *Paper Presented at the Third Penannual Workshop on the Workshop Conference*, Indiana University, 2–6 June 2004.
- Stuhlmann, F. (1909) *Beiträge zur Kulturgeschichte von Ostafrika*. Deutsch-Ostafrika, Bd. X, Dietrich Reimer (Ernst Vohsen), Berlin, Germany, 905 pp.
- Tewa, C. (2014) Favoriser la gestion du risque climatique par les agriculteurs et les pêcheurs: Diagnostic agro-économique de la Région de Kipo (zone de plaine inondable le long de le fleuve Rufiji–Tanzanie). Mémoire de fin d'étude, UFR Agriculture Comparée et Développement Agricole, AgroParisTech/AFD/Sokoine University of Agriculture, Paris, 105 pp.