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Managing climate risk to build resilience in the most food-insecure areas of the world. The Senegal case.

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Man never made any material

as resilient as the human spirit.

Bern Williams

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Introduction

The principles and the issues advocated by the United Nations have always raised broad interest in me, until I decided to channel this enthusiasm into concrete actions. In 2015, I took part to "Rome: Model United Nations", a training program that annually gathers hundreds of students from all around the world to stage the work of United Nations' member States and Committees by applying UN official rules of procedure. On that occasion, I represented the Senegal delegation at FAO, with the purpose of raising awareness about Senegalese food- and energy- related issues and making sure they were properly considered – together with those of 190 Countries – when drafting a final resolution that ratified FAO commitment in coping with humanitarian emergencies. Following that experience, I kept nurturing my interest and curiosity for UN reality until I chanced upon the precious opportunity to work for and in the World Food Programme, the UN frontline agency in the fight against hunger. Witnessing the wonder in people from the global South when I managed to make their life a little bit easier, made me realize that we, "the Westerns", take for granted too many things. This inspired me to deepen the knowledge of what can be done to bridge the gaps in their ability to deal with the daily difficulties imposed by the economic, social and natural environment around them. The energy that flows in those people cannot be blocked by the same things we cope with here with extreme simplicity; conversely, it has to be channeled to grow stronger and more resilient. "Risk Management" was the subject that, more than any other, would have provided me with strategic and analytical tools to address this study as thoroughly as possible and prove how a proper management of risk (before, during and after the adverse event) can be determinant in building resilience.

In order to contextualize the research, I identified a social setting (the global South, specifically Senegal), together with a risk (climate risk) and an appropriate risk management framework, namely the one to which the strategic partnership between

Oxfam America and World Food Programme gave life in 2012: the R4 Rural Resilience Initiative.

The first chapter opens with the examination of the direct proportionality between poverty and vulnerability to weather-related risks, explaining how the disparity in resources, knowledge and technologies throughout the world is such that shocks of the same entity hitting, for example, Bangladesh and France entail vastly different impacts. When losses inflicted by natural catastrophes meet the limited access to income-generating opportunities, the result is a compromised human welfare and a longer loss-recovery period. The evidence of such a disorder in crisis periods proves the need for climate risk management strategies. Here comes the R4 project, which four components and their interrelation are detailed here and later in the paper. The chapter closes with the analysis of the relationship between risk management and social protection systems, highlighting the reasons why the expenditures in a preventive, comprehensive and reasoned approach should be considered as investments rather than costs.

In the second chapter, I investigated the application of the enterprise risk identification framework in a context that well differs from the business reality. In particular, it has been applied to introduce the main risks faced by rural communities, thus shedding light on the sources of risk that threaten the agricultural sector and the livelihoods of those who depend on it. A prioritization of these perils based on their likelihood and severity leads to narrow them down to a list of key risks that are more likely to cause adverse impacts on production yields, incomes, and livelihoods, and on which the qualified Government should concentrate attention and resources. The paper focuses on weather-related risks, in particular on droughts, which The World Bank proved to be the major source of risk for agricultural production, due both to their frequency and severity in the last thirty years. Among the four main risk management approaches (mitigation, transfer, coping and avoidance), the high-to-medium frequency and magnitude that characterize droughts drives to focus on risk transfer mechanisms, among which Weather Index Insurance is probably the most feasible to adopt in poor Countries: it is flexible, cheap and it provides policyholders with both protection against income and consumption losses (since payouts' rapid distribution prevents from undertaking detrimental coping strategies) and with an instrument that can enhance their creditworthiness, work as a collateral and therefore increase their borrowing opportunities.

The purpose, scope, technical specifications and flaws of Weather Index Insurance are presented in chapter three, while the fourth and last chapter offers an example of how it is being implemented in Senegal, one of the four Countries where R4 partners are now concentrating their efforts and resources. Here, weak infrastructures, pronounced inequalities and lethargic economy combine with the arid climate of western Sahel, resulting in difficult living conditions and environmental degradation. This originates the high vulnerability of Senegalese people to external shocks and natural disasters, a scenario that makes Senegal a suitable Country where to assess climate risk and study the effectiveness of risk management strategies in building people's resilience to natural disasters.

An impact evaluation commissioned on Senegal revealed the success achieved thanks to this insurance product that, together with microcredit, livelihoods diversification, community savings and creation of assets to reduce risk exposure, is alimenting a virtuous cycle that is driving local community towards food security, higher productivity and improved income.

Nothing more than the words of the recipients themselves of the initiative can confirm that we are on the right path. This is what Ibrahima Diop, Deputy Mayor of the village of Mereto – Eastern Senegal – said when he was asked what the R4 initiative meant for his village: "*To me, R4 means Reap, Remuneration, Rejoice and Revitalization: the program enables us to harvest more (Reap) through the use of adapted seeds, support, agricultural materials and guarantees through insurance, it helps sell more (Remuneration) to have more financial resources and be happier (Rejoice), and to reinvest and revitalize the household (Revitalization)*[1]".

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[1] R4 Rural Resilience Initiative – Annual report | January-December 2015, World Food Programme and Oxfam America

Chapter One

Climate, poverty and the role of risk management. The contribution of R4 Rural Resilience Initiative

With his "quantitative delirium" and the foolish exploitation of natural resources, Man is unceasingly challenging the environmental limits that define the finite nature of our system. This unsustainable administration of ecosystems and the consequent climate change have heavy impact especially on the poor, since they are more dependent on natural environment and on the goods it provides.

The R4 Rural Resilience Initiative is a strategic partnership between the World Food Programme and Oxfam America, that is, the United Nations frontline agency in the fight against hunger and a global organization committed in addressing social injustices worldwide. Since 2012, the aim of such a strong and dedicated combination of forces has been the improvement of food and income security of rural households, whose poor economic conditions and undiversified investments make them highly vulnerable to climate change. The initiative builds on the implementation of a sustainable natural disaster risk management framework, that addresses in four complementary ways the issues encountered by the most climate-vulnerable people, with the aim of mitigating the financial and social impacts of natural calamities and thus alleviate the resulting food insecurity.

1.1. The direct proportionality between poverty and vulnerability to natural disaster risk

The effects of climate change are rapid and unequivocal: desertification, soil erosion, increasing temperatures, shrinking water tables, extreme climatic events, phenomena whose frequency or intensity harm mainly those whose livelihood depends on agriculture.

In particular, according to what reported by the Intergovernmental Panel on Climate Change in its *Fourth Assessment Report*[2], the climate change is expected to provoke at minimum the following consequences:

- Higher frequency and intensity of extreme weather events (hurricanes, floods, droughts, etc.);
- Shift of the growing season and change in rainfall patterns;
- Warming of air and ocean temperatures, glaciers melting;
- Rise of sea level and subsequent salination of aquifers and agricultural lands;
- Decreased water quality and availability in arid and semiarid regions.

The concreteness of climate change has been documented in many relevant studies and databases, among which it is possible to read that, between 1980 and 2006, the number of climate-related disasters quadrupled and the number of individuals hit rose from 170 to over 250 million per year[3].

Moreover, the World Bank estimates that its adverse consequences are likely to increase the number of people who are at risk of hunger and to potentially push an additional 100 million individuals into poverty by 2030, most of them living in the Global South, along coastlines, in river deltas or on islands, where climate change has become a dominant fact of life.

On this purpose, in 2004, Oxfam America published the results of a comparative study according to which earthquakes of similar magnitude impact Japan and Peru, yet in Japan the average death toll amounts to 63 people each year, against the 2900 registered in Peru. Likewise clear is the example provided by Hurricane Georges, which in 1998 caused the death of 589 in Haiti and the Dominican Republic but only

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[2] The IPCC was established in 1988 by two UN organizations (WMO and UNEP) to provide the world with a reasoned and objective view of the state of understanding of climate change, its multiple consequences and the options for mitigation and adaptation. Further reports, published in 1990, 1995, 2001 and 2014 collect and assess researches from over 2000 scientists with the aim of inducing governments to adopt the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

[3] EM-DAT International Disaster Database of OFDA (Office for Foreign Disaster Assistance) and CRED (Centre for Research on the Epidemiology of Disasters): http://www.emdat.be [Accessed August 8, 2016]

6 people in Cuba[4]. These evidences confirm that, empirically, poor areas are more prone to natural disasters than prosperous ones, a concept that well differs from the propensity to natural hazards: shocks of the same entity can hit Bangladesh and France but entail vastly different impacts.

This concept was also touched by UN Secretary-General Ban Ki-Moon, who remarked how people in the least developed countries are those who did the least to cause climate change, «yet they stand to lose their homes, jobs, and even their lives because of its growing impacts [5] ».

This disparity in knowledge, resources and technologies available throughout the world calls for prompt and global action in order to support food-insecure people in limiting losses and enhancing resilience in the face of natural disaster risk.

Farmers in the industrialized countries can count on a multiplicity of solutions that help them overcome uncertainty-related issues: for example, advanced technologies and investments in scientific research allow to preserve crops from harmful parasites or rain lack; a capillary information and telecommunication system fosters knowledge and expertise sharing; the modern infrastructures present in most of these countries allow the rational employment of natural resources and the rapid and cheap transport of goods that reach those in need while maintaining their freshness. Likewise important are the variety of insurance policies against specific types of risk, the possibility to trade in commodity futures and options and the relative ease of borrowing (for consumption or production purposes) and thus compensate for bad crop yields.

Different is the context where rural households live in developing countries: weak infrastructures and degraded ecosystems magnify the effects of floods and droughts, causing significant impacts even after low-intensity shocks. Other factors that hamper a smooth growth in the Global South are the communication barriers,

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[4] "*Weathering the storm: Lessons in risk reduction from Cuba*", Oxfam America, 2004.

[5] *"UN Secretary-General's initiative aims to strengthen climate resilience of the world's most vulnerable countries and people"*, official website of the United Nations: http://www.un.org/sustainabledevelopment/blog/2015/11/un-secretary-generals-initiative-aims-to-strengthen-climateresilience-of-the-worlds-most-vulnerable-countries-and-people/ [Accessed August 8, 2016]

educational deficiencies, fragile and rudimentary institutional settings, unfair economic policies, the difficulty to obtain credit from ordinary financial intermediaries. Of course, there is no shortage of initiatives to tackle these issues: for example, many farmers rely on community networks and moneylenders to help themselves cope with income falls. However, these risk-sharing strategies have a big limitation, since their participants often come from the same geographical region or even the same village, meaning that they face the same risks and are hit by the same events, which implies limited opportunities to provide mutual support.

The adverse effects of climate change are not the only risk that rural households have to face: the situation is fuelled by many other risks that exacerbate the food insecurity. In developing countries, in fact, they also have to deal with economy's vulnerability to financial shocks, volatile commodity prices (even riskier when the local economy depends on few commodity exports), multinational corporations' expansive interests, conflicts and, more recently, terrorism threat. Inevitably, this combination of factors puts under pressure the livelihoods of the poorest, who are consequently forced to embrace detrimental coping strategies, such as the sale – at loss – of productive assets (e.g. livestock), the withdrawal of children from school, the reduction of food quality and consumption, the tendency to spend less on health care, initiatives that trap them in long-term poverty and marginalization.

To sum up, natural and human-induced disasters are the main menaces to food security in all its dimensions:

- **Food availability** in adequate quantities and on a steady basis;
- **Food accessibility**, which is the possibility to procure nourishment regularly and in a safe manner, through domestic production, purchase, barter or food aid;
- **Food quality**, in terms of sufficient nutritional intake to maintain a healthy and active life;
- **Food utilization**, which should entail hygiene, storage and cooking practices to preserve its freshness and properties.

Disaster losses (current or in the form of fall of potential income) are accentuated in poor villages where the higher susceptibility to natural threats and the limited access to markets and income-generating opportunities result in stances that harm the human welfare and lengthen recovery after disasters. The evidence of such a behavior in crisis periods proves the general expensiveness or absence of adequate natural disaster risk management strategies.

1.2. The R4 model: four practices to mitigate climate risk

Launched in 2012 in Ethiopia and Senegal[6] and recently expanded in Zambia and Malawi, the R4 project builds on the respective strengths of WFP and Oxfam America to mitigate natural disaster risk through the implementation of a risk management framework that combines mutually supporting risk management strategies and integrates them into productive safety net programs.

As the name of the initiative suggests, four are the risk management components envisaged by the project:

R1 – Risk Transfer via the underwriting of a disaster insurance within everyone's reach.

R2 – Risk Reduction by implementing resource management activities to reduce the potential damages and increase resilience to adverse climatic events.

R3 – Prudent Risk taking, taking advantage of a sounder asset base and using insurance as collateral, R4 farmers can easily access microcredit and become more confident in undertaking riskier (hence, more remunerative) activities, investing in productive inputs or hiring labor, since they know that their financial risk is minimized by the insurance subscribed and by the livelihood diversification they manage to achieve.

R4 – Risk Reserves, in form of individual and group savings, which could be both financial and accumulated in-kind.

[6] The project is rooted in the Horn of Africa Risk Transfer for Adaptation initiative (HARITA), born from the collaboration of Oxfam America, Swiss Re and Relief Society of Tigray and launched in Ethiopia in 2011. HARITA pioneered the rural risk management introducing the "insurance for work" apparatus: Ethiopian poorest farmers were given the opportunity to pay for crop insurance with their own labor.

1.2.1. Risk Transfer

Risk transfer strategies play a critical role in disaster risk mitigation and adaptation to climate change, since they promote a proactive approach to face climate risk by providing immediate liquidity after – or before – a disaster.

The transfer of risk can occur formally or not[7]. In the first case, governments, insurers and large risk-bearing entities develop mechanisms to help people and companies manage event-related losses. Among them, insurance policies, catastrophe bonds[8] and reserve funds[9].

Informal risk transfer, on the other hand, takes place in community networks and families and builds on expectations of mutual aid in the form of credit or contributions.

Insurance is the most common formula of risk transfer, where the financial consequences of a specific negative event are shifted from a party (the insured) to another (the insurer), who provides coverage in exchange for premiums payment or, in a limited number of cases, in exchange for labor provision. Insurance companies are aware that not all the insured individuals will suffer losses simultaneously so, given their large number of clients, they pool all the premiums and thus manage to work profitably and pay for potential claims.

In particular, the risk transfer solution adopted by the R4 initiative is the so called *Weather Index Insurance*[10], a financial product linked to an index that measures rainfall level in the geographical region where the reference weather station is placed. The mechanism is used to insure local rural households against drought or flood-related crop losses: payouts are triggered when the index hits an agreed threshold that is expected to result in a crop loss due to scarcity or excess of rainfall

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[7] *Terminology on DRR*, official website of The United Nations Office for Disaster Risk Reduction: https://www.unisdr.org/we/inform/terminology [Accessed August 10, 2016]

[8] CAT bonds are high-yield debt instruments issued by insurance companies to transfer risk to investors. Their structure implies that, if the event considered in the contract occurs (earthquake, hurricane, etc.), then money is raised as a form of payout recognized to the insurer.

[9] Savings account or other highly liquid assets set aside by an individual or company to cover unexpected costs that may arise in the future.

[10] It will be addressed more in detail in Chapter Three.

in a certain period. In comparison with the traditional agricultural insurances, this product presents a much lower threshold of insurability and a simple structure, features that allow reaching a wider range of rural households. Moreover, WII does not require in-field assessment of the damages, since payouts only depend on objective data such as the initial value of the crop insured and the degree to which the index is below or above the threshold set. This contract design presents pros and cons: on the one hand, it reduces transaction costs and allows a rapid issuance of the payouts, essential to prevent farmers from undertaking the negative coping strategies mentioned before. On the other hand, it generates *basis risk*, which is the potential mismatch between the payouts triggered and the actual loss suffered that derives, for example, from the different microclimates affecting the area[11].

Besides transferring the risk away from the farmer and its family, WII offers added value to the policyholder. Thanks to the support of advanced satellite technology, it is possible to obtain early warning signals, thus planning the payouts ahead of the climatic disaster and issuing them when farmers need them the most. This encourages policyholders to undertake activities aimed at containing damages (if still possible), sustaining their family during the adverse period or investing in technology and assimilation of agricultural information.

Moreover, WII can serve as a collateral to obtain credit at better rates. In the developing world, the difficulty to access regular financial institutions is well known. Holding a policy insurance makes impoverished people more creditworthy, therefore it may help them obtain small loans to start their own business and stop depending univocally on agriculture. The insurance policy would thus work as a way for the lender to secure the loan: if the borrower fails to pay it back, the creditor can seize the collateral and recoup the loss.

Given its nature, WII suits better where natural hazards and terrain are homogeneous in a widespread area and where the correlation between weather and crop yield is high. Accordingly, this financial product does not work properly in geographic areas characterized by a variety of microclimates, localized risks and

[11] Basis risk will be addressed in chapter three.

other complex conditions, since it would be difficult to assess to which degree the crop is impacted by a specific climatic event.

Despite the perceived sophistication that WII might seem to have, the structure of this insurance contract, that will be further detailed in the next chapters, is far more simple than the one that traditional insurances have: not only the number of parameters to be set to outline WII's mode of operation is low, but these technicalities are also decided *after* discussing with the recipient themselves of the coverage, namely the farmers, who know their needs and obstacles better than any insurance expert. These meetings are made even more productive by first arranging dedicated educational sessions in the rural communities in order to raise awareness among farmers, agricultural development agents and other stakeholders about insurance principles and potential, and thus provide them with the "instruments" to proactively participate to a financial discussion. In all the Countries where R4 is active, there are organizations in charge of delivering such trainings, for example the Organization for Rehabilitation and Development in Amhara (ORDA) in Ethiopia, the International Research Institute for Climate and Society (IRI) in Senegal, Vision Fund Zambia (VFZ) in Zambia and Balaka District Council in Malawi, which have all reached thousands of farmers and stakeholders. Auxiliary associations are then active to intermediate between insurers and the rural community to assist the policy subscription and all the following procedures.

To conclude, WII is delivering valuable results where implemented and has the potential to give a big contribution to agricultural development and adaptation to climate change, especially in the highly vulnerable areas of the developing world. However, it is and should remain only one of the elements of a wider risk management framework that aims at eradicating poverty and building resilience to natural hazards.

1.2.2. Risk Reduction

This branch of the R4 framework includes activities designated to build or rehabilitate assets and resources in order to increase productivity, reduce vulnerability and enhance resilience to climate risk.

In such a context, *Insurance For Assets* works as bridge between risk transfer and risk reduction activities, because it gives the poorest households the opportunity to pay crop insurance premiums not by cash but through the engagement in risk reduction activities or community environmental improvement projects (e.g. building erosion control systems, planting trees, etc.). Therefore, the program has the potential to incentivize the commitment in disaster prevention because the insurer agrees to offer lower premiums to reward a risk-reducing behavior.

IFA systems are generally supported and provided by existing governmental social safety nets; however, WFP has recently developed a program based on a similar principle: the *Food Assistance For Assets* program, in fact, incentivizes vulnerable people to build or maintain assets useful to face natural hazards in exchange for cash transfers, vouchers and food donations.

The rationale of both initiatives is that the execution of resilience-enhancing activities implies a reduction of the potential damage caused by the adverse event, therefore the payouts foreseen by the insurance or the vouchers distributed would need to be lower in value.

Risk-reduction initiatives may range from farm system monitoring procedures, to activities that aim at enhancing production, to efforts designated to restore fragile ecosystems and reduce the impact of climate shocks in the most degraded and shock-prone environments. Examples of what contemplated in these plans are the installment and maintenance of irrigation systems, the implementation of conservation agriculture[12], the building of community warehouses and comfortable

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[12] FAO studies and practitioners' expertise confirm that conservation agriculture is a valuable tool for Sustainable Land Management. CA activities are based on three principles: minimal soil disturbance, crop rotation and permanent soil cover, which integration has the potential to preserve agricultural productivity, profitability and sustainability in the long-term.
Conservation Agriculture, official website of FAO: http://www.fao.org/ag/ca/ [Accessed August 13, 2016]

roads and bridges, the adoption of soil and water conservation techniques (e.g. terracing and dams), land and swampland reclamation, the construction of flood defense and drainage systems, and even the facilitation of the access to markets and other places where community members can share products, ideas or disseminate meteorological information[13].

The combination of these activities has primary importance in the fight against food insecurity since only concrete actions and tangible results can alleviate the root causes of food uncertainty, foster a rapid shock recovery and lay foundation for long-lasting resilience.

1.2.3. Prudent Risk Taking

High vulnerability to the adverse effects of climate change makes rural households in the Global South hesitant to hire labor and invest in productive inputs, due to the uncertainty about their crop yields and, therefore, the low return expectations. Moreover, the perceived risk of default pushes microcredit institution to limit the lending activity, especially in proximity to the bad season.

The – forced – choice to make low investments in productive inputs keeps farmers stuck into a mediocre production system, where outputs – and income – are unable to take a growth path.

The mutual support that characterizes R4 strategies here becomes evident: the underwriting of index insurance, the building of productive assets and the recovery of natural resources minimize the financial risk associated with natural disasters and consequently boost farmers' food security and confidence, resulting in the capacity to obtain more credit. This encourages rural households to choose higher-risk/higher-yield solutions, invest in diversified activities and purchase fertilizers, seeds, technologies and whatever capable of improving their productivity, resulting in a virtuous circle that has the potential to pull farmers out of chronic poverty.

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[13] *Building resilience through asset creation*, World Food Programme, November 2013. http://documents.wfp.org/stellent/groups/public/documents/communications/wfp261744.pdf?_ga=1.225084314.1205205840.1467122641

1.2.4. Risk Reserves

Risk reserves consist in individual and group savings that give farmers a sound financial base on which to count during adverse circumstances. These reserves can also be made of natural products, for example farmers can store surplus yields, cereals, seeds or oxen in designated banks.

Small-scale funds and silos act as a self-insurance mechanism for participants, who can draw money or foodstuffs from these buffers in order to face unpredicted shocks and satisfy short-term needs.

Building risk reserves means combining two aspects essential to people sustenance: first of all, acting with forethought is necessary when outputs and incomes of an entire community depend on unpredictable and potentially devastating events, which leave no choice or time once occurred. This behavior reminds of the basic principle of insurances, where policyholders "deposit" cash when they are active and less needy, in order to have it back when they need it the most. Secondly, setting up group reserves is a valid way to weave together social relationships and concretely express the mutual support that should characterize any community. Of course, people who live in the same geographical region and belong to the same village, are most likely hit by the same event simultaneously, a circumstance that lessens their ability to provide mutual support. However, different microclimates and barriers (natural or man-made) may entail dissimilarity of the effects of an adverse episode, and consequently produce needs of different size and urgency.

The last concept is linked to the idea of social cohesion, a likewise useful "tool" in the fight against food insecurity.

The multiple definitions of social cohesion prevent its meaningful and thorough measurement. In the last three centuries, in fact, many sociologists and psychologists have carried out much theoretical and empirical research on this concept. A review of the relative key studies highlights that their theories cluster around the following main aspects: interdependence and solidarity among a group's members, cooperation as a behavior that leads to mutual benefits, sense of belonging and feeling of morale. Combining these inputs into a single definition, we can refer to social cohesion as to that set of behaviors and kinship ties between individuals or communities sharing the same values, aimed at strengthening the group solidarity – especially when it is threatened – and mitigate the frustration that may derive from social disparities. With this in mind, it is clear that supporting social cohesion and acting accordingly, means perceiving problems as common and not limited to individuals. Hence, cooperation and participation become ways to promote collective accountability and address issues that hit the entire community, thus increasing the ability of vulnerable households to cope with natural disasters.

1.3. The role of risk management in supporting social protection systems

As delineated by the United Nations Research Institute for Social Development (UNRISD), social protection is a broad set of arrangements that aim at «preventing, mitigating and overcoming situations that adversely affect people's well-being»[14].

Poor people, who find access to formal risk management strategies more difficult than those with greater possessions, are less willing to engage in high risk–high return activities, due to the higher variance of their expected income, and thus they risk to perpetuate in a vicious cycle that traps them into deep poverty. As a consequence of this, they tend to engage in "self-protection" mechanisms such as larger savings and accumulation during good times or community measures to pool and share risks. However, these initiatives are often insufficient to support them after a big shock, a situation that forces to cut back on meals or pool children out of school. This makes public interventions necessary.

People, by their nature, are exposed to a big variety of potentially hostile circumstances that can harm their security and safety, especially those of the critically poor: geographical location, economic and political context of belonging, social and health conditions, age and many other factors of natural or human origin

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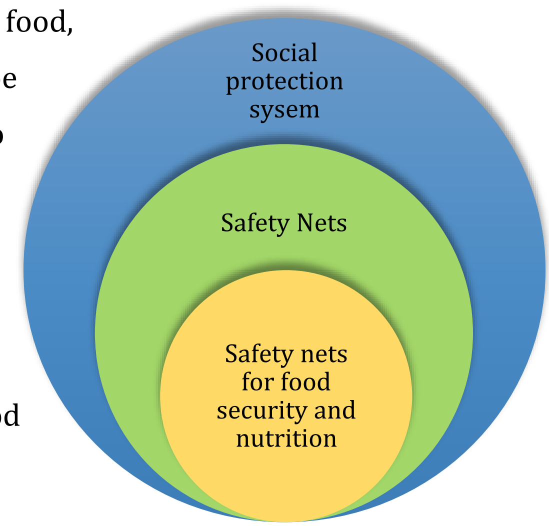
[14] "*Combating Poverty and Inequality*", UNRISD, 2010.

that social protection systems try to address in an equally large number of ways. At a minimum, they include safety nets, social services (primary in education and nutrition fields), labor market policies and insurance options for the most vulnerable (e.g. health and crop insurance, contributory pensions).

The functions that social protection systems exercise through these branches are mainly four:

- **Prevent** indigence, hunger and any other form of physical and intellectual deprivation that harm human dignity;
- **Promote** projects that increase people's real income, support them in building productive assets and in absorbing the knowledge needed to escape poverty;
- **Protect** vulnerable people against injustices and hazards and help them climb out of poverty;
- **Transform** current marginalization situations by implementing empowering programs and anti-discrimination laws.

In particular, over the last three decades, there has been an exponential growth in the number and reach of safety net programs, arranged in almost any country where a broader protection system is set[15]. They can be targeted or universal interventions that aim at facilitating access to basic essentials, for example through non-contributory transfers in the form of in-kind food, productive inputs, vouchers or cash to be distributed to needy people in order to prevent them from further deprivation and lift their chances up.



For the purposes of this dissertation, focus is made on the safety nets built to mitigate the effects of natural disasters, alleviate food insecurity and strengthen resilience.

[15] The World Bank, in its *World Development Report 1990*, recognized their importance. Not by chance this period coincided with the collapse of communism, the continuation of debt and economic crises and the rising share of elderly people in developing countries.

A Social Risk Management framework that effectively supports this kind of safety nets should, firstly, be preventive, thus reinforce ex ante the structural solidity of the society to support it in withstanding shocks. Designing safety nets in advance of potential menaces implies drafting guidelines and time plans, ensuring enough human resources and their immediate availability in case of appeal, assigning responsibilities to apposite departments. Secondly, this plan of action should be complemented by a range of measures – that fall outside the domain of safety nets – to regulate labor standards, investment policies, land rights, environmental policies and infrastructures building. This approach would satisfy both prevention and mitigation needs: in fact, on the one hand, it prevents from land degradations, reduces the probability of climatic and human-induced disasters, thus decreasing the variance of people's expected income. On the other hand, this mechanism reduces the potential damages of a hostile episode. Risk coping is essentially the residual strategy if everything else has failed, due to insufficiency of the precautionary measures or the magnitude of the happening. Once the adverse event occurs, the trigger of safety nets follows a range of decisions regarding the appeal process, the target beneficiaries, the intensity of the intervention, distribution and monitoring procedures and a final evaluation phase. During or after the adverse event, a well-functioning safety net helps vulnerable people maintain access to basic social services and essentials instead of merely delivering transfers. This increases recipients' future productive capacity and their resilience, a result that leads to consider expenditures in safety nets as investments rather than costs. Such a preventive, comprehensive, reasoned approach also presents a big value addition: by focusing on the causes rather than on the symptoms of poverty and food insecurity, it helps eradicate them and gradually channel affected people on a growth path that breaks poverty boundaries.

Chapter Two

Identification, assessment and management of climate risk

Although this dissertation addresses only one type of risk (climatic), a specific transfer strategy (insurance) and a specific insurance policy (weather-index) in a particular economic and social context (developing Countries), the chapter applies the risk identification framework to briefly introduce the main risks that farmers face and that threaten the different phases of the agricultural supply chain. Afterwards, focus is made on climate-related risks and on the issues arising during the qualitative risk assessment stage, especially when estimating likelihood and severity of the related worst-case scenarios. The findings are subsequently applied to a real case, where expert-based deliberations are expressed for observed and projected climate changes at a global level.

The chapter emphasis is then further narrowed on droughts, floods and the respective causes, consequences and monitoring models.

The chapter then approaches climate risk management and investigates more in deep the risk transfer strategies, in particular agricultural insurance products.

2.1. Identification of the risks faced by rural households

In order to address thoroughly the identification of the risks faced by rural households, it is necessary to consider the three main components of risk identification[16]:

1. Risk categorization and definition
2. Qualitative risk assessment
3. Emerging risk identification

[16] This methodology is typical of the value-based Enterprise Risk Management approach, however, the basic principles common to any type of risk (such as deviation from expectation, likelihood and severity) allow its application – even if at higher level – to the analysis of climate risk.

This investigation is fundamental for the correct execution of the following steps (e.g. the identification of the most feasible mitigation strategies), since they rely on information provided at this stage of the study.

2.1.1. Risk categorization and definition

A valid starting point consists in the structuring of a list of the potential risks faced by the population under consideration. The resulting Risk Categorization and Definition (RCD) tool displays risk categories, specific risks faced and a definition clarifying the scope of the related risk.

Before its drafting, it is important to bear in mind that for the RCD to be effective, defining risks by source is a central key for success. However, it is a common mistake to confuse classification by source and classification by intermediate or final outcome.

For example, reputation risk is not a risk: reputational damage may be the outcome of several risk sources, such as the quality of a product or internal fraud. Nevertheless, it is not even a true outcome, or at least the one that matters the most. It is the financial consequences following the reputational loss, for example higher cost of capital and lower future revenues, the ultimate and most significant result.

Failing to define all risks consistently by source lowers the quality of the risk identification, quantification and especially decision making.

Firstly, defining risks by outcome generates confusion in the experts designated to evaluate the risk, who would imagine different sources and, consequently, may identify likelihood and severity on an inconsistent basis. Also the quality of the risk quantification process would be negatively influenced, since the ambiguity of a risk that is improperly defined by outcome makes it difficult to identify the subject matter experts (who depend on the source) and imagine individual and complete risk scenarios[17]. Finally, the decision making process would be compromised since most mitigation is performed at the source of the risk, while in this case the evaluators

[17] When the risk source is not correctly identified, it is difficult to imagine other possible intermediate or final outcomes.

would be led to consider possible mitigation options to address a risk that is not the real one, a behavior that would let the real risk source keep being active and potentially harmful.

Table 2.1 shows the RCD tool for the categorization of the risks faced by rural households. It includes:

- Risk source.
- Risk category, which could be *operational* (unexpected changes in elements related to operations, such as processes, human resources, disasters, technology and assets), *strategic* (unexpected changes in strategy formulation and execution) and *financial* (unexpected changes in external markets).
- Specific risk and level of covariance, which indicates the extent to which the related risk is correlated among individuals. This can range from purely idiosyncratic/uncorrelated (micro), regionally covariant (meso) to nationwide covariant (macro).
- Main effects on farmers.

Table 2.1 – RCD tool for key risks faced by rural households

Risk Source	Category	Specific risks and level of covariance			Effects
		Micro (idiosyncratic)	Meso	Macro (covariant)	
Weather-related risks	Operational	-	- Rainfall - Temperature variability - Hailstorm	- Hurricane - Strong winds - Flood - Drought	Lower yields, loss of productive assets and income
Hydrogeo - logical risks	Operational	-	- Landslides - Soil erosion - Volcanic activity	- Inundation - Earthquake	Lower yields, loss of productive assets and income
Biological risks	Operational	-	- Contamination	- Pests - Disease	Lower yields, loss of income
Labor and health risks	Operational	- Illness - Death - Injury	-	-	Loss of productivity, loss of income, higher costs to bear
Policy and political risks	Strategic	-	-	- Regulatory changes - Political upheaval	Potentially higher taxes, difficulty in accessing markets
Price risks	Financial	-	-	- Volatility	Potentially lower prices, loss of income
Market risks	Financial	-	-	- Unfavorable exchange rates - Market supply and demand	Loss of potential income

The coexistence of multiple risks that have the potential of influencing each other makes it difficult to fully address certain constraints: that is, mitigating or transferring a certain risk may not be enough to free farmers from restrictions and obstacles since these last can be driven by many risks simultaneously. Access to financial intermediaries represents a clear case in this sense. As mentioned in the first chapter, formal banks require a level of creditworthiness that people in the Global South often do not have, due to the uncertainty regarding their businesses and the volatility of their income. At the same time, microcredit institutions limit the lending activity in proximity of the bad season, when adverse climatic events can reduce the solvency probability of the borrower. Addressing climate risk through agricultural insurances or risk reduction strategies is a valuable way to increase the financial solidity of the farmer and secure the loan, however many other risks could keep menacing its restitution. For example, water contamination, infestations, landslides may destroy the crop so that nothing remains to sell by the due repayment date, or prices may fall to such an extent that the revenue earned is insufficient to repay the loan in full. Many other risks may derive from different levels of the supply chain, which in the agricultural field is also known as "*farm to fork*".

Figure 2.2 reports some examples of the risks that threaten the different phases of the agricultural supply chain, each of them spanning another supply chain and its underlying risks. This complexity gives some insights into the extent of the risks faced by farmers and their potential to exacerbate each other. Therefore, to manage them effectively, it is needed the cooperation among all the actors involved and the use of sophisticated tools that developing Countries rarely have.

Figure 2.2 – Some of the risks affecting different stages of the supply

Stages	Purchase of the inputs	Production	Storage	Processing	Distribution
Type of risks	Weather and hydrogeo - logical	Biological, weather and hydrogeo - logical	Hydrogeo – logical, logistics, management	Management and operations, logistics, infrastructure	Market, logistics, infrastructure, politics
Examples	Floods, droughts or hailstorms reduce crop yields thus increasing seeds price	Hurricane destroys productive assets, contamination affects food safety	Physical destruction, robbery, perishability	Inability to adapt to changes in labor flows, poor management decisions, poor quality control, forecast and planning errors, energy costs	Changes in supply and demand that impacts quantity and prices, degraded transportation, interruption of trade due to political instability

For the purposes of this dissertation, for the topicality of the issue and for the extent of their effects, focus is made on weather-related risks.

2.1.2. Qualitative risk assessment

This is the second component of the risk identification process and its purpose is the prioritization of the potential risks in order to narrow them down to a list of key risks on which to focus mitigation, transfer and/or coping strategies.

The ranking is done by considering three main variables:

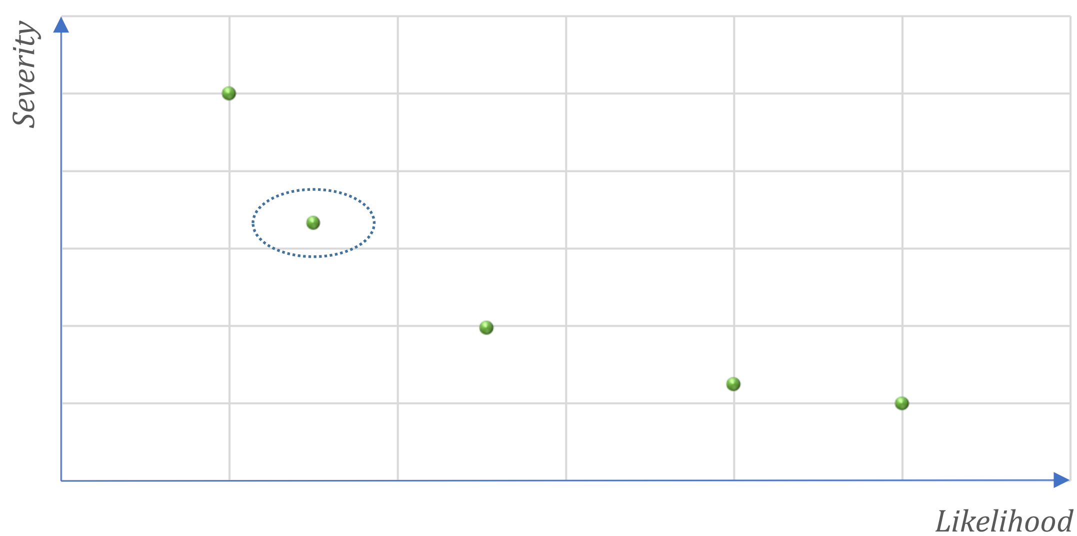
- **Hazard**: the risk is categorized by assessing its *frequency* (likelihood of occurrence), *severity* (potential financial consequences in case of happening) and *spatial extent* (amplitude of the impact – Single person? Village? Entire Country?), which coincides with the level of covariance.
- **Vulnerability**: extent to which the adverse event may affect the population, their livelihoods and assets taking into account the managing strategies already in

place. It depends on deficiencies, weaknesses and lack of resilience of the system exposed.

- **Exposure**: it depends on the location of farms, crops, livestock and warehouses and the related riskiness[18].

Per each risk identified, for the assessment to be effective, a clear definition of the likelihood and severity metrics is a central key for success. Here it becomes evident the need for a correct execution of the risk categorization and definition phase, since a risk properly identified by source makes it easier to identify the associated scenarios (both pessimistic and optimistic) in a complete and univocal way. A step further towards the consistency of the likelihoods and severities assigned to each risk identified, would be the identification of a credible worst-case scenario[19], which is neither the most unlikely of the events, nor the most common, yet it is robust enough to capture its full impact.

Chart 2.3 – Credible worst-case scenario



[18] It is a common mistake to use vulnerability and exposure as synonyms, yet they are distinct: exposure is a necessary, but not sufficient, determinant of risk. It is possible to be exposed but not vulnerable, for example thanks to the availability of buildings that mitigate the risks. On the contrary, to be vulnerable to extreme events, it is needed to be exposed.

[19] S. Segal, *Corporate Value of Enterprise Risk Management*, New Jersey: John Wiley & Sons Inc., 2011, p. 135

Considered the position where the event is placed in the grid, it can be assimilated to an (almost) extreme scenario.
At this point, it is necessary to distinguish between extreme weather events and extreme climate events. The discrimination argument is the time scale over which they happen: extreme weather events are the result of changing weather patterns that occur within short time periods (from sub-daily to weekly fluctuations); extreme climate events happen over longer periods as a consequence of the accumulation of several weather events of not necessary high magnitude (e.g. when, within a season, the sequence of moderately below-average rainy days leads to below-average cumulated rainfall and, therefore, to drought).

The following paragraphs address extreme climate events, which likelihood and severity can be explored and quantified through the combined use of surveys, observations, analysis of the physical processes, modeling tools and simulations. The other risks faced by farmers and the related estimates are out of the scope of this paper. Therefore, the prioritization of all these threats according to their riskiness will not be executed.

2.1.2.1 Likelihood

Besides the uncertainty deriving from randomness – unavoidable especially when dealing with climate events – it is important to also consider the uncertainty generated by *insufficient agreement* in the model projections, the uncertainty due to *insufficient evidence* (inadequate number of scenario simulations, lack of observational data, poor understanding of the underlying processes, etc.) and the one caused by *insufficient literature* (lack of published studies and projections)[20].
The IPCC *Fifth Assessment Report* provides an uncertainty guidance[21]: in particular, for each assessment, an expert provides a confidence level (high, medium or low)

[20] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 131

[21] *Ivi*, p. 120

considering the confidence in the model adopted, the physical understanding, the robustness of data, the homogeneity[22] of the observations, etc.

- For assessments with *high confidence*, the following likelihood ranges can be associated with a direction of the change:
  - Virtually certain: 99 – 100%
  - Very likely: 90 – 100%
  - Likely: 66 – 100%
  - More likely than not: 50 – 100%
  - About as likely as not: 33 – 66%
  - Unlikely: 0 – 33%
  - Very unlikely: 0 – 10%
  - Exceptionally unlikely: 0 – 1%

  In case of high confidence but lack of sufficient model projections to estimate the likelihood, only the confidence assessment should be provided.
- For assessments with *medium confidence*, the direction of change can be provided but without the related likelihood.
- For assessments with *low confidence*, no direction of change can be provided but only the reasons behind the judgment.

As mentioned before, *insufficient evidence* is one of the issues that may hamper the likelihood assessment: in particular, data availability is especially critical when analyzing the extremes of climate variables, such as droughts when considering precipitations, hurricanes when considering winds, etc. The more rare the event, the more difficult is the assessment because of the fewer cases that can be considered compared to common events (such as precipitations or winds in their average levels). Another element that restrains data availability is the time scale over which extreme events occur, since it determines the temporal intervals at which the observations need to be registered.

[22] Data are homogeneous when fluctuations and trend followed over a time frame are only explained by variations in the climate patterns. This means that biases due to even small changes in the measurement equipment can negatively influence data homogeneity and reliability.

Empirically, data measured at the end of long time frames (monthly, seasonally, annually) for temperatures and precipitations have been recorded for most parts of the world starting early in the 20th century and they allow the assessment of droughts or wet periods occurred over a month or longer. On the contrary, data in the order of short time scales (daily, hourly) have been recorded starting only in the second half of the last century and not even everywhere. Moreover, many Countries do not easily share them and the quality of their measurement is questionable[23].

2.1.2.2. Severity

Also the severity metric has to be defined clearly; a best-practice in this field consists in agreeing on a single metric able to fully capture the financial impacts of the event[24]. However, climate risk implies such a level of complexity that a single severity metric cannot capture the full impact. Catastrophic events can have limited financial costs but high human costs, while others may cause big economic losses and a low number of victims.

Limiting the study to the immediate financial consequences of the adverse event, a valid metric could be the *value of the yields sold*, since it captures the loss in quantity and quality of the harvests and the people tendency to buy less during adverse periods. However, it does not capture the cumulative effects of the disaster (on human capital, assets, potential income, etc.), which can even reflect on the capacity of the community to deal with future calamities or restore initial revenues (e.g. a flood causes a landslide that drags half of the terrain thus impeding to keep harvesting the same quantities).

The large number of variables and assumptions to consider is making risk modeling the ideal tool to work out thorough quantitative estimates for financial losses.

Among the essential variables to consider when assessing agricultural risk, there is the relationship between the agricultural calendar and the timing of the calamity: in

[23] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 123

[24] S. Segal, *Corporate Value of Enterprise Risk Management*, New Jersey: John Wiley & Sons Inc., 2011, p. 136

fact the vulnerability of livestock and crops, and therefore the potential economic impact, depends on the season, on the growth stage and on many idiosyncratic variables such as crop variety, soil quality, microclimates, presence of irrigation and drainage systems, etc.

Numerous additional variables and the interdependency between vulnerability and exposure overload the assessment process. For example, a village can be exposed to floods but not to hurricanes, severe events can introduce risky factors into new areas or reveal preexisting ones, poverty and lack of social protection systems can exacerbate the community vulnerability, the lack of appropriate information can lead to wrong perceptions that negatively influence the ability to undertake mitigation strategies. These factors can be summarized in the following points:

- Microclimates and idiosyncratic environmental elements;
- Human intervention as a mechanism that may increase exposure and vulnerability of a certain community;
- Socioeconomic conditions (social protection systems, communication infrastructures, poverty level, demographic density, governmental initiatives, etc.).

As a result of this, vulnerable groups are not only at risk because of their exposure to hazards, since, as previously mentioned, exposure does not necessarily imply defenseless. The condition of vulnerability depends on a complex set of drivers and interrelated conditions among which not less important is the role of Man: communities are both victims and actors, therefore any mitigation approach is incomplete if it does not address human behavior too.

2.1.2.3. Qualitative assessment of natural events – data from the real world

By collecting data and assumptions from numerous scientific studies, the IPCC has developed a summary of the observed and projected weather and climate changes at a global level[25]. They are grouped into three categories:

1. Extremes of atmospheric weather and climate variables (temperature, precipitations and wind)
2. Phenomena that influence the happening of weather and climate extremes or that are extremes themselves (monsoons, El Niño, tropical and extra tropical cyclones)
3. Impacts on the natural environment (droughts, floods, dangerous sea levels and coastal impact, waves, landslides, etc.)

Table 2.4 illustrates results only for some variables and extreme events which consideration is more relevant for the purposes of this dissertation[26].

The confidence and probability assessments reported in the table are expressed according to the guidance reported in the paragraph *Likelihood* and derive from expert-based deliberations that take into account the confidence in the model used, the available data and the other uncertainty sources previously listed.

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[25] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 119

[26] The entire table can be found in the above-mentioned paper.

Table 2.4 – Observations and projections at global level of climate-related extremes

Natural events		Observed changes (since 1950)	Attributions of observed changes	Projected changes (up to 2100) compared to late 20th Century
Weather and climate variables	Temperature	*Very likely* decrease in number of unusually cold days and nights at the global scale. *Very likely* increase in number of unusually warm days and nights. *Medium confidence* in increase in length or number of warm spells or heat waves in many regions. *Low or medium confidence* in trends in temperature extremes in some sub-regions due either to lack of observations or varying signal within sub-regions.	*Likely* anthropogenic influence on trends in warm/cold days/nights at the global scale. No attribution of trends at a regional scale with a few exceptions.	*Virtually certain* decrease in frequency and magnitude of unusually cold days and nights. *Virtually certain* increase in frequency and magnitude of unusually warm days and nights at the global scale. *Very likely* increase in length, frequency, and/or intensity of warm spells or heat waves over most land areas.
	Precipitations	*Likely* statistically significant increases in the number of heavy precipitation events (e.g., 95th percentile) in more regions than those with statistically significant decreases, but strong regional and sub-regional variations in the trends.	*Medium confidence* that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale.	*Likely* increase in frequency of heavy precipitation events or increase in proportion of total rainfall from heavy falls over many areas of the globe, in particular in the high latitudes and tropical regions, and in winter in the northern mid-latitudes.
Phenomena related to weather and climate extremes	En Niño	*Medium confidence* in past trends toward more frequent central equatorial Pacific El Niño-Southern Oscillation (ENSO) events. *Likely* trends in Southern Annular Mode (SAM).	*Likely* anthropogenic influence on identified trends in SAM. Anthropogenic influence on trends in North Atlantic Oscillation (NAO) are about *as likely as not*. No attribution of changes in ENSO.	*Low confidence* in projections of changes in behavior of ENSO and other modes of variability because of insufficient agreement of model projections.
Impacts on physical environment	Droughts	*Medium confidence* that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but opposite trends also exist.	*Medium confidence* that anthropogenic influence has contributed to some observed changes in drought patterns. *Low confidence* in attribution of changes in drought at the level of single regions due to inconsistent or insufficient evidence.	*Medium confidence* in projected increase in duration and intensity of droughts in some regions of the world, including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Overall *low confidence* elsewhere because of insufficient agreement of projections.

	Floods	Limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scale. Furthermore, there is low agreement in this evidence, and thus overall *low confidence* at the global scale regarding even the sign of these changes. *High confidence* in trend toward earlier occurrence of spring peak river flows in snowmelt- and glacier-fed rivers.	*Low confidence* that anthropogenic warming has affected the magnitude or frequency of floods at a global scale. *Medium confidence to high confidence* in anthropogenic influence on changes in some components of the water cycle (precipitation, snowmelt) affecting floods.	*Low confidence* in global projections of changes in flood magnitude and frequency because of insufficient evidence. *Medium confidence* that projected increases in heavy precipitation would contribute to rain-generated local flooding in some catchments or regions. *Very likely* earlier spring peak flows in snowmelt- and glacier-fed rivers.
	Sea level and coastal impact	*Likely* increase in extreme coastal high water worldwide related to increases in mean sea level in the late 20th century.	*Likely* anthropogenic influence via mean sea level contributions.	*Very likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels. *High confidence* that locations currently experiencing coastal erosion and inundation will continue to do so due to increasing sea level, in the absence of changes in other contributing factors.

The frequent lack of robust observations, the uncertainty issues and the composite set of variables that influence the cumulative outcome of an extreme event limit the quality (or increase the difficulty) of the likelihood and severity assessment, hence projections of future patterns cannot always be made with a high level of confidence. Their credibility varies with the *weather variable*, with the *temporal and spatial scale* of the measurement and with the *intensity* of the event type.

In particular, comparison between observed and simulated climate conditions demonstrates more certainty when considering some climatic variables than others. Data reported in the table confirm that mean temperature is a variable that climate models track with a good level of confidentiality, especially when measured over longer time horizons[27]. Moreover, it has been observed that models that account for

[27] J. Räisänen, *How reliable are climate models?*, Tellus Series A - Dynamic Meteorology and Oceanography, 2007, vol. 59, p. 2-29

both natural and human factors, consistently reproduce the variation in the decennary global average temperature. On the contrary, without anthropogenic elements, they fail to replicate real data. Disparity can also be detected between models that simulate or project temperature fluctuations in small spatial domains and those that reproduce global scales, with the former being much less reliable because of the "noise" that characterizes minor areas[28].

Confidence in projections for extreme events is generally weaker than for projections of long-term averages[29]. However, forecasts regarding extreme temperatures tend to be more consistent than those that project precipitation extremes, such as frequency, distribution, and intensity of heavy precipitations[30] , agricultural droughts[31] and floods. This is due to the lower number of cases that can be considered compared to regular events.

According to the data reported in the table, it is possible to conclude that almost all the changes occurred in the late 20th century can be attributed with medium confidence to the anthropogenic influences, especially the changes to the water cycle that affects floods.

The qualitative risk assessment leads to the ranking of the potential risks according to the severity and likelihood that characterizes the worst-case scenario of each risk. A dispersion analysis may help identify scores for which there is not a clear initial consensus. They can assume a bimodal or highly disparate form: the first case highlights that there are mainly two different opinions regarding the riskiness of a specific situation, while the highly disparate shape indicates the complete absence of consensus. Discussion generally addresses most of the discordances.

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[28] E. Hawkins and R. Sutton, *The potential to narrow uncertainty in regional climate predictions*, Bulletin of the American Meteorological Society, 2009, pp. 1095-1107.

[29] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 132

[30] D.A. Randall et al, *Climate models and their evaluation* in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the IPCC Fourth Assessment Report,* Cambridge and New York: Cambridge University Press, 2007, pp. 589 - 662

[31] G.L. Wang, *Agricultural drought in a future climate: results from 15 global climate models participating in the IPCC Fourth Assessment Report*, Climate Dynamics, 2005, pp. 739-753

Once the level of consensus has been enhanced, the qualitative scores are finalized and only the most highly ranked risks are selected. This final classification of the key risks is advanced to the risk quantification phase for the development of appropriate mitigation tools, while the entire list is kept updated for the emerging risk identification.

2.1.3. Emerging risks identification

The identification of emerging risks requires both scanning the environment to detect unknown risks and monitoring known risks to detect changes that could increase their ranking position enough to let them become key risks.

When considering climate risk, these two components can be approached through the simulation of weather conditions, the projection of future patterns, the investment in research and the gathering of information from any other reliable sources.

2.2. A closer look at droughts and floods

This paragraph examines two of the most critical natural (and, sometimes, man-induced) risks that threaten rural households and the entire community exposed. Droughts and floods are firstly presented by considering their triggering causes and the consequences on agricultural production and human activity. Then, the main indices and models adopted to monitor and project their changes are illustrated.

2.2.1. Droughts

Droughts can be defined as "a period of abnormally dry weather long enough to cause a serious hydrological imbalance[32]". There is plenty of reasons that may lead

[32] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 167

to droughts, and this makes it difficult to accurately forecast changes in their intensity, duration and place of happening (as Table 2.4 confirms).

Scientific literature distinguishes between[33]:

- *Meteorological drought:* the most common type, which is due to lack of precipitations;
- *Soil moisture drought:* also known as agricultural drought, it is due to an increase in water evapotranspiration from the ground that leads to deficit of soil humidity. The causes could be the enhancement of wind speed, weak vapor pressure (that can be caused by higher temperatures) and higher radiations.
- *Hydrological drought*: negative anomalies in surface and ground water levels;
- *Socioeconomic drought*: water scarcity induced by human activity.

A closer look at these root causes can unearth "positive" implications. In fact, the discrete nature of the elements that trigger each kind of draught implies that, in case of happening, its intensity will not be equal in all the regions affected. For example, the same lack of precipitations or increase in radiations over a certain geographic area will have consequences of different entity depending on the quality of the soil, the local vegetation or the interrelation of other factors: a short-term rain deficit in a very humid area might not threaten crops thanks to the abundant moisture reserve in the terrain. At the same time, the coexistence of more negative factors has the potential to increase the duration or intensity of the drought: persistence of anomalies in the circulation of surface and ground water, persistent lack of precipitations in a given region, insufficient soil moisture, they are all factors that may seriously extend the drought duration.

On the consequences side, the impact of the lack of water – the most critical of the natural resources – may induce many dangerous coping mechanisms. In fact, the repercussions of water deficit on rural livelihoods and the economic losses experienced in agricultural production can trigger fierce competition for scarce

[33] R.R. Heim Jr., *A review of twentieth-century drought indices used in the United States*, Bulletin of the American Meteorological Society, 2002, pp. 1149-1165

resources, migration flows, higher probability of conflicts outbreak and exacerbation of the ethnic tensions.

If droughts "basic" consequences are combined with difficult socioeconomic conditions, the resulting situation is exponentially worsened. The United Nations have estimated that most of the people frequently affected by droughts are also below the poverty line (that is, each of them lives with less than 1 USD per day) and live in areas characterized by strong food price volatility[34]. The resultant income drop forces households to sell assets, borrow more money, reduce food consumption – which inevitably leads to malnutrition – and withdraw children from school to let them work and participate to family income-generating activities.

An example of this combination of negative and mutually strengthening factors is provided by the Mediterranean Countries, especially the eastern and southern ones, particularly prone to droughts, already protagonist of harsh conflicts (and, consequently, seriously food insecure) and theatre of migratory events.

How to monitor droughts

The variety of factors that can trigger droughts implies a likewise ample range of indices that can be used to monitor their occurrence and pattern and that can be classified according to the variable tracked. This ample choice implies that projections of future changes widely depend on the reference index chosen.

Table 2.5 illustrates some of the indices most frequently adopted[35].

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[34] Mainly deriving from currency devaluation, which makes imports more expensive thus limiting the available commodities, and from the outburst of armed conflicts that lead to scarcity of the basic food and resources supply.

[35] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 168

Table 2.5 – Common indices used to monitor droughts

Variable tracked	Index name	Mode of operation	Thresholds
Precipitations	Standard Precipitation Index **(SPI)**	Translate long-term precipitation records (3, 6, 12 or more months) into normal distribution with Mean = 0 and SD = 1 Its time frame allows to account for accumulated precipitation deficits.	SPI > 2 : extremely wet 1,5 < SPI < 2: severely wet 1 < SPI < 1,5: moderately wet 0,5 < SPI < 1: mildly wet -0,5 > SPI > -1: mild drought -1 > SPI > -1,5: moderate drought -1,5 > SPI > -2: severe drought SPI < -2 : extreme drought
	Consecutive Dry Days **(CDD)**	Maximum consecutive number of days without rain (<1 mm) in a specific period, generally year or season.	-
Precipitations and evapotranspi - ration	Palmer Drought Severity Index **(PDSI)**	Measurement of the gap between actual or potential moisture balance and its normal conditions. It has to normalized according to the local characteristics.	-
	Standardized precipitation-evapotranspiration Index **(SPEI)**	Examination of persistent anomalies in precipitations and evapotranspiration levels.	-
Soil moisture	Simulated Soil Moisture **(SMA)**	Moisture balance is simulated by taking into account mainly surface and ground water circulation and precipitations.	-

2.2.2. Floods

Floods consist in "the overflowing of the normal margins of a stream or other body of water, or the accumulation of water over areas that are not normally submerged[36]". As it happens with droughts, floods also can be the consequence of

[36] IPCC, *Managing the risks of extreme events and disasters to advance climate change adaptation*, New York: Cambridge University Press, 2012, p. 175

many disparate events, such as ice or snow rapid melting, coastal flooding, intense or persistent rainfalls, dam break (that, for example, may contain a glacial lake). Their severity is reduced or increased depending on the drainage conditions of the hit basin, first of all the soil status, hence its slope, frozenness, moisture content and the presence of engineering developments that allow the flow regulation, such as dikes, sea walls, urban drainage systems and structured use of the land.

Flooding consequences are wide ranging as its causes: interruption of water and food supply and damage of crops are the most common ones, but the financial impact of such a disaster may go far beyond the agricultural or livestock loss: compromised cultivated land, landslides, disruption of dams and connection facilities, if present, imply expensive dismantlement and rebuilding costs and the lengthening of the recovery period.

How to monitor floods

The hydrological model is the most commonly used to study floods patterns in the scenario of climate change (thus, leaving out the changes related to engineering development and anthropogenic influence) and it operates by running simultaneously a land surface model and a river routing model. However, the limited spatial coverage of this tool and the relatively recent history in the data recording represent a great limitation to the confidentiality with which intensity, frequency and sign of floods changes has been measured. This lack has been partially offset by the use of pre-instrumental data, collected from archives and geological indicators that, studying the sediments and biological traces deep under the soil surface, have revealed longer-term information such as the occurrence of "paleofloods".

The limited evidence that causes uncertainty and difficulty to identify weather-driven floods tendencies is also accompanied by the confusing adoption of the above-mentioned engineering practices and, more in general, by the massive human activity. In fact, despite the low confidence (explained again by limited evidence) that Man has affected the frequency and severity of floods, there is high confidence that he has influenced some components of the hydrological cycle which, therefore, has implications on floods. The second and last element for which there is high confidence is the earlier occurrence of spring peak flows in snow- and ice- fed rivers, though this might not imply a higher magnitude of the flow in the concerned regions.

2.3. Managing climate-related agricultural risk

2.3.1. Risk management approaches and adoption level

There are mainly four approaches to risk management:

- **Mitigation**: limitation of the potential adverse impacts of natural hazards. In agriculture, this could be done through the plantation of seeds resistant to excess or scarcity of water, crops and livestock diversification, installment of soil irrigation and drainage systems, crop calendars, etc.
- **Transfer**: transmission of the potential negative financial consequences of a certain event from a vulnerable party to someone else. The most common form of risk transfer is insurance, however risk sharing and risk transfer within a family or community are very common practices in the developing countries.
- **Coping**: activities performed after the event manifestation but that can be planned ex-ante in order to reduce their implementation time when the event strikes. This allows responding quickly, reducing losses and improving resilience.
- **Risk avoidance**: also known as risk prevention, it consist in completely avoiding that a certain unpredictable event (as climate events are) causes financial or physical losses. However, it is rarely feasible in developing countries and in agricultural environment, since people here do not have many alternatives to farm-related employment and income.

These approaches can entail more or less formal risk management mechanisms that can be adopted at *micro*, *meso* and *macro* level, that is, at household, community, market and government level. Generally, the higher the level, the more formal the approach. Households tend to adopt informal initiatives, which often coincide with savings, crop and income diversification, reasoned management of crops and livestock, water resource management. Community-level approaches may depend on its extension and stability, ranging from informal to semiformal, such as mutual aid and shared food buffer stocks. More formal initiatives are undertaken at market level, for example insurance, formal lending and saving, use of new technologies. At the top step, there is the government, which is the entity in charge of implementing weather data systems, state-sponsored insurances and other services, emergency relief, agricultural research, infrastructures, etc.

This allocation of duties and roles, known as *risk layering*, reflects the fact that each level is characterized by a specific ability to handle the risk (either financially or physically) and each of these entities is called to play its role to address that risk to ensure that also the other parties do the same and collectively manage the given risk. If one party were absolved, the others might lose incentive to invest in risk management thus increasing the likelihood or severity of the risk itself. Moreover, risk layering represents a fundamental starting point for the implementation of a risk management framework since it allows to clarify *who* carries *which* part of the risk and *how much* of it, thus guaranteeing prompt and coordinated action before and after the occurrence of the adverse event.

All these strategies are fundamental to help withstand moderate climate risks, however catastrophic events of high magnitude could reveal some inefficiencies in the risk management system: such an event hits a broad scale of people and communities, therefore diversification strategies (at least those implemented in a short range of action) would fail since households would experience losses in all the crops; community initiatives would not be sufficient since the entire community would need aid and would not be able to provide mutual support; if everyone starts selling assets this would depress local prices, making the proceeds insufficient to sustain the family; catastrophic events would also discourage financial intermediaries from extending loans and insurance policies to farmers given the big losses experienced and future uncertainty.

2.3.2. Correlation between crop yields and climate conditions

Correlation between agricultural damage and adverse climate event is not straightforward, unless the event is such rapid and extreme that the dependency results obvious. On the contrary, when the event is prolonged over a long time frame, it could be difficult to assess to what extent the production loss depends on it since the damage could have occurred at any earlier stage, other events may have influenced the yields or the household could have had the opportunity to reduce the loss.

A strong correlation can be found in drought-prone areas – such as those in Southern Africa – where there is a clear seasonality and where rainfed crops are vastly planted: delay in the rainy season or prolonged water scarcity can produce devastating consequences (that is the case of maize crops in Zambia and Malawi). The correlation becomes less evident in areas where wet conditions are more regularly distributed across the year and, therefore, where there is a weaker seasonality, or areas where many other events such as conflicts, diseases and contaminations can influence harvests quality and quantity.

Weather-yield relationship becomes even weaker where there is a considerable human intervention, for example where there are irrigation and drainage systems.

This diversity makes generalization about the relationship in object unable to bring trustful results: each environmental context presents unique features to consider in order to correctly assess the relationship between climate event and crop damage.

2.3.3. Agricultural crop insurance: products overview

As mentioned in paragraph 1.2.1. , insurance represents the most common choice when opting for a risk transfer solution, since it provides policyholders with both protection against income/consumption losses (since payouts distribution prevents from undertaking detrimental coping strategies) and with an instrument that can enhance their creditworthiness, work as a collateral and therefore increase their borrowing opportunities.

On the market there are many crop insurance products, which can be classified into two major categories based on how claims are calculated[37]:

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[37] Ramiro Iturrioz, *Agricultural Insurance*, Washington DC: The World Bank, 2009

- **Indemnity-based crop insurance**: the claim is based (and assessed) on the actual loss suffered by the policyholder. There are two alternatives:

  1) *Damage-based indemnity insurance (Named Peril)* is such that the sum insured coincides with the expected revenues or the production costs, while losses are computed in the field shortly after the disaster occurrence by assessing a percentage of the damage suffered. If the measurement cannot be done immediately, it is deferred to a later moment in the season. The indemnity is equal to this percentage times the sum insured (and minus deductibles that can be applied to reduce moral hazard by encouraging the policyholder to prevent losses)[38].

  Indemnity =

  *Percentage of Damage * Tot. Sum Insured — Deductible*

  This policy is generally underwritten when the risk to which the farmer is exposed is hail, frost, violent precipitation or fire; it is not suited to complex perils.

  2) *Yield-based crop insurance (Multiple Peril)* consists in the farmer insuring a yield (called guaranteed yield) which dimension is established as a percentage (generally 50-70%) of the historical average – or expected – yield of the farmer, depending on the crop type and geographical region. The sum insured can be computed considering the future market price of this guaranteed yield. Claims depend on the realized yield: if it is lower that the guaranteed yield, the indemnity equals the difference between guaranteed and actual yield, times future market price of the seeds[39], times insured unit area. This allow to align the indemnity with the insured amount.

  Indemnity =

  *(Guaranteed Yield – Actual Yield) * FMP * IUA*

[38] This product can also account for franchises, which represent a threshold of loss that is necessary to hit to make the insurance trigger payouts. Its purpose is the reduction of claims frequency.

[39] Consequently, this product could be exposed to price risk.

This policy is chosen when crops are exposed to multiple perils (specific perils can be explicitly excluded in the contract), hence when it is difficult to identify the exact loss origin.

- **Index-based crop insurance:** the claim is based (and assessed) on the value of an index, thus skipping in-field measurement of the losses. The index tracks a weather variable such as temperature, rainfall, river level, etc. A prerequisite for the successful implementation of such a contract is that both the contracting parties have confidence in the index objectivity, to achieve which it is necessary the high correlation between the index and the crops losses (see paragraph 2.3.2.), the parties' abstinence from index manipulation and the availability of sufficient data. There are two alternative insurance products built on indices:
  1) *Area yield index insurance*: the insurer designs an index based on the guaranteed yield for a given country or district. This insured yield is generally equal to 50-90% of the average yield of the area. The claim is recognized if the realized average yield of the area is lower than the insured (or guaranteed) one, regardless of the policyholder's actual yield.

Indemnity =
Guaranteed Yield – Actual Yield

2) *Weather index insurance*: a specific weather parameter based on the detections of a specific weather station is monitored over a certain time frame. The policy is designed to protect the farmer against index realizations that coincide with events that entail crop losses. This means that payouts are distributed when the index value exceeds or is below a prespecified threshold during the insurance period. The indemnity amount can be equal to the total sum insured or can vary according to how far the index deviates from the agreed thresholds.

This product is increasingly being adopted to manage drought- and temperature-related risks.

In developing Countries, insurers may often find challenging the provision of agricultural insurance because of the uncertainty to which farmers are subdued, given the close dependency of their business on weather conditions. This results in premiums that are often prohibitive for rural households. Moreover, it seems that farmers are more prone to buy coverage if they also have access to other services, such as credits and markets, which allow them to enhance their proceeds and pay premiums with more serenity. The widespread absence of these facilities represents a discouraging factor and reduces insurances' attractiveness.

This, calls for government and international markets intervention: the former can act as a catalyst for insurance promotion – at micro, meso and macro level – by investing in meteorological services and providing regulatory frameworks. Therefore, this promotion aims at all those actors involved – at different levels – in the risk management framework. By fostering risk layering and clarifying roles and responsibilities, financial intermediaries have the possibility to choose whether to retain or transfer risk according to their risk appetite and financial capacity; in case they decide to transfer it, reinsurance companies will have already been identified in the risk layering framework and, thanks to a reinsurance agreement, insurers will have the opportunity to boost their capital, lower the premiums and underwrite more risks. On the other hand, international markets' intervention becomes necessary in case of extremely rare and catastrophic events that are not sustainable by commercial insurance companies. Moreover, since the financial commitment for reconstruction and the implementation of safety nets are entitled to the local government, there could be the risk of it withdrawing this type of support for political and fiscal reasons. An appropriate risk financing strategy (e.g. a contingent line of credit, weather derivatives) should be arranged to limit the fiscal exposure of Government to excessive losses. Extra capacity may be obtained by pooling drought risks in a regional facility and then transferring them to international reinsurance and capital markets.

Chapter Three

Weather Index Insurance: features, strengths and areas of improvement

The identification and assessment of climate risk (in particular droughts and floods) *in the scenario of developing Countries* leads to acknowledge the inappropriateness of traditional agricultural insurance in managing weather-related agricultural risk. That kind of policy, in fact, would imply in-field assessment of damages, a procedure that both upsurges transaction costs (charged to insurance premiums) and delays payouts distribution, thus leaving farmers no chance but undertaking detrimental coping strategies in the period between disaster occurrence and indemnity payment. In addition, traditional insurances are designed to be applied to localized risks and complex conditions, a feature that impedes the application of the same contract on a group of people, which – on the contrary – is another prerequisite that ensures low administrative and operational costs and, therefore, a low threshold of insurability. No less important is the transparency and objectivity of the parameters on which an indexed insurance is built, essential to build trust between farmers and insurers.

Based on these considerations, it is now time to examine more in detail what Weather Index Insurance is and what it is not.

3.1. Purpose and scope

Weather Index Insurance has the objective of helping most climate-vulnerable people get out of the poverty trap where they are stuck because of the combination of risks and disadvantages that block their opportunities. However, it is necessary to notice that its role is the augmentation of an already existing value proposition, an integrated risk management framework that is already functioning, as the one implemented within the R4 Rural Resilience Initiative. In case of lack or difficulty to access markets and financial institutions, Weather Index Insurance cannot express its full potential and unlock growth (especially credit) opportunities, which represent the starting point for the enhancement of people resilience against climate change.

In particular, WII supports vulnerable rural households in coping with *current* weather-related risks and, if accurately designed and based on reliable technologies, perhaps also *future* risks triggered by climate change, thus significantly contributing to the sustainable development of these communities. Moreover, since WII is linked to and index rather than actual losses, it overcomes the application limits that traditional crop insurances face, especially in developing countries. In these areas of the world, Weather Index Insurance has two broad purposes (IFAD and WFP 2010):

- WII for development, to promote agricultural development and help rural households, input retailers and financial intermediaries manage covariate risk that has low-to-medium-frequency (droughts and excess of rainfall).[40]
- WII for disaster relief, as an alternative method to fund disaster recovery assistance.

Of course, Weather Index Insurance is not faults-free and it has to account for many challenges: contracts should be affordable, easy to understand and locally manageable, flexible enough to meet the needs of many diverse areas and conditions, they should be blended in with existing risk management policies and able to deliver their results in areas lacking (or weak) of regulatory systems, markets and distribution channels. Another significant problem is the shortage of historical data or lack of technology to capture real time data[41] in the areas most in need to manage climate risk. Weather data, in fact, represent the cornerstone of this insurance product since the index and related thresholds are designed starting from the consideration of the loss probability, which is partially derived from historical data.

[40] Covariate risks affect many people simultaneously and with the same intensity, so it is more difficult to address them with micro-level strategies than are more localized risks.

[41] This latter issue can be addressed just by installing weather stations and rain gauges in the most remote and needy regions of the world. However, the lack of historical data is less easy to be solved. Technology can provide an important help on this: backward analysis and simulations based on available satellite data can support the construction of "synthetic weather", thus backfilling missing gaps.

Regarding its scope, index insurance can be adopted to manage a wide range of weather-related risks, such as crop and livestock loss caused by droughts, floods, strong winds and harsh winter conditions. It is also suitable for application at different social levels:

- *Micro* level: small-scale farmers and households can insure their production based on temperatures and rainfall detected by local weather stations. These micro policies can be purchased as stand-alone products or within a package (e.g. credit, agricultural information, etc.), meaning that they can also be distributed to final holders by Financial Service Providers (FSPs), input suppliers, farmers' associations, Microfinance Institutions (MFIs) which have broader and more direct relationships with the target group than most insurers and also have vested interests in protecting their clients against adverse weather events. In fact, by making them purchase the insurance, these intermediaries benefit from the sounder financial stability of their customers: credit institutions can link WII to their lending operations and thus reduce default rates caused by weather shocks, while agribusiness firms may devise the link between WII and their products as a source of competitive advantage.
- *Meso* level: the same intermediaries mentioned above can also be policyholders. The insurance can be designed as a policy issued to (and purchased by) the organization (FSP, MFI, input supplier, etc.) but with payouts that can either directly or indirectly benefit the farmers that they have as customers in a certain geographic area. The Index Insurance, in fact, provides coverage to the aggregator that, in turn, hands down its benefits to farmers through a variety of services (e.g. credit packaging, contract farming or charging lower operating costs). In this way, the intermediaries protect their own exposure because they reduce the credit risk assumed by providing their typical services and alleviate mass loan defaults when weather shocks hit the area.
- *Macro* level: governments and relief agencies could benefit from an index insurance based on domestic weather observation, since they would receive early liquidity following disasters and consequently they could lessen the risk of famine

deriving from big losses in the stable crop. This would result in an enhanced national disaster management framework and in more rapid coping initiatives.

This paper focuses on delivery of Weather Index Insurance at *micro* level.

3.2. Contract design

3.2.1. Contract structure and basic assessments

Weather Index Insurance is a contract which performance depends on an objective parameter that measures a climate variable (millimeters of rain, temperature level) at a specific weather station during a defined time period. The parameter is set in order to obtain the highest possible correlation with the crop loss suffered by the policyholder as a consequence of the adverse event related to the variable monitored. When the parameter hits critic values that (may) correspond to an agricultural loss, all the insured policyholders who live in the area to which the weather station refers, receive payouts based on the same contract, thus field assessments are not required.

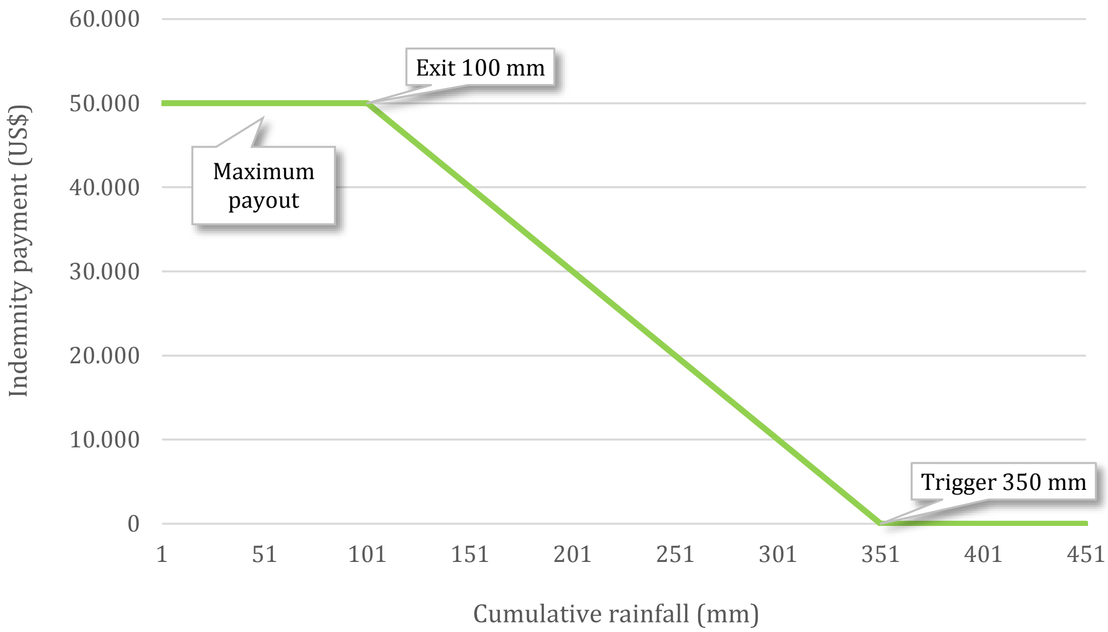
Here is a list of WII "ingredients" and, where possible, the alternative options in which they can be presented:

- *Reference weather station*, where weather variable data are detected.
- *Insurance period*, which coincides with the crop life cycle and is generally divided into phases of measurement (typically three phases for grain crops).
- *Trigger value* of the weather variable at which payouts start to be distributed. It is possible to choose among different options, mainly depending on the variable monitored: the measurement can be cumulative (the most efficient when monitoring rainfall), average, maximum or minimum. Triggers must be set at levels where the crop actually starts to be water-stressed.
- *Payout structure*, that can be lump sum or incremental. In the former case there is a single value payout, in the latter one a defined monetary amount is paid per each unit deviation below (or above) the trigger value.

- *Limit* of the measured parameter, below (or above) which no incremental payment is applied. It coincides with the *exit* value, at which the maximum payout is made if the index value equals this threshold. This level is set to represent a critical rainfall amount at which the crop is severely damaged.
- *Premium,* which coincides with the cost of the policy, paid by individual farmers in exchange for the risk transfer service. WII contracts are characterized by a single premium rate per product, equal to all the insured parties in the target area.

Chart 3.1 shows the typical payout structure of a WII contract designed to transfer drought risk. It is clearer when read from right to left: when the cumulative rainfall level equals 350 millimeters (*trigger value*), payouts start to be distributed; above this rainfall level, no indemnity is paid. In this example, the payout structure is incremental, meaning that per each unit deviation below the 350 millimeters an incremental payment is recognized up to the total amount of 50,000 US$, which are distributed when the cumulative rainfall level hits the amount of 100 millimeters (*exit value*). In the unlucky case in which the cumulative precipitation is less than 100 millimeters, no incremental payments are distributed.

Chart 3.1 – Example of t e payout structure of a WII drought contract.



The detection of the index level is executed per each measurement phase that composes the insurance period. On this purpose, of particular importance is emphasizing that the rainfall timing, and not only the rainfall amount, is essential to satisfy the soil water balance needed to deliver the expected ultimate yield. In fact, even if the cumulative precipitation fallen during the crop season is tolerable, dry periods occurred during critical phases of the crop growth can cause harvest loss anyway. This is, for example, the case of maize, which yields are particularly sensitive to rainfall during the tasseling and yield formation stage (from June to September), when the amount of rain determines the grain size. On a general basis, we can distinguish three phonological phases: seeding/establishment, vegetative growth/flowering and yield formation/ripening.

Each phase in which the crop season is subdivided is associated with a specific weather parameter threshold below which payouts are issued. By distributing this liquidity in advance of the ultimate harvest, rural households have the possibility to undertake activities that help avoiding or reducing the expected loss.

Designing a WII contract requires "science and art". The former is needed to build a mathematical model that serves as proxy for losses, able to capture the relationship between the weather variable and the potential loss and design the index that is most likely to trigger indemnity payments when (or before) loss occurrence. The latter, regards the gathering of qualitative and technical knowledge from farmers and experts to make the model reflect the reality (and thus minimize the basis risk, the imperfect correlation between the index and the yield of farmers[42]).

On a general basis, structuring a WII contract requires starting with the identification of the risk that the insurance should cover, since not all the risks to which farmers are exposed can be addressed with an index insurance. Completed this phase, it is necessary to proceed with the assessment of the hazard, exposure and vulnerability of the potential insured people and crops (this process coincides with the qualitative risk assessment procedure illustrated in chapter two). The outputs of such studies are the probability of occurrence of the climate risk identified, its potential intensity and the resulting potential damages. These pieces of information represent the basics to design the index, structure the WII contract and price it adequately.

3.2.1.1. Climate risk identification

To make WII products' underlying index a trustable proxy for losses, it has to be centered on an objective parameter (millimeters of rain, temperature level, etc.) that presents high correlation with the variable of interest (crop yield). This parameter must meet prerequisites such as ease of observation, transparency, periodical detectability, observability over a wide area, properties that make WII work better when applied to *highly correlated and covariate* risks[43], such as droughts, floods and

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[42] B.J. Barnett, C.B. Barrett, J.R. Skees, *Poverty Traps and Index-Based Risk Transfer Products*, World Development, volume 36, issue 10, 2008, pp. 1766–1785.
Available at: http://linkinghub.elsevier.com/retrieve/pii/S0305750X08001356 [Accessed October 1, 2016].

[43] Meaning that the agricultural damage is a clear consequence of that climate risk (correlation) and that the insured parties are all affected by the same degree (covariance).

harsh temperatures. On the contrary, idiosyncratic (or local) hazards such as fire and hail are better addressed through the implementation of indemnity-based crop insurances.

Besides these considerations, the choice of the “right” risk to transfer requires the interaction between insurance experts and customers. The former have the means to make a thorough analysis of the current risk management framework and can also run agricultural system monitoring[44]. Customers, on the other hand, deeply know their risk exposure, their soil and crops’ criticalities and, more generally, their needs. The mutual sharing of this knowledge, which should also involve interviews, surveys and focus groups with all the stakeholders, is also known as *participatory stakeholder process*[45] and is fundamental to identify which risk to transfer and if WII is the right instrument to do that. During this and the following phases, index designers model potential indices and submit them to customers’ feedback, for example to review payout frequency, premiums amount, number of phases that should compose the covered period, etc. This process should result in an index that provides payouts when losses are experienced, eliminating as much basis risk as possible.

3.2.1.2. Exposure assessment

The objective of the exposure assessment is the analysis of crops’ behavior in different stages of the plants growth in response to changes in weather conditions; plants, in fact, react differently depending on the phase of the crop cycle they are in, and some of these phases may be particularly critical to the crop quality or survival. This analysis, which should be led by an agronomist, is fundamental to design an index truly capable of catching the right crop needs and thus differentiate between rainfall timing, rather than limiting the detections to the rainfall accumulated over a

[44] It helps investigating the interaction between environment and crop (or livestock) systems in order simulate real scenarios and detect the impacts that rainfall, temperature, soil nutrients etc. *simultaneously* have on crop yields. This helps designing better-correlated indices and, thus, reduce basis risk.

[45] Hellmuth M.E., Osgood D.E., Hess U., Moorhead A. and Bhojwani H. , *Index insurance and climate risk: Prospects for development and disaster management*. Climate and Society No. 2. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, 2009, p. 22

unique and longer period. To capture this variation, experts resort to the weighting of rainfall: a higher weight in the critical periods, since a rain shortage in these periods would be much more deleterious than in any other phase of the cycle.

The crop model elaborated considering the plant's life cycle and water needs is useful to quantify the potential losses caused by extreme weather events that concern that specific weather variable and provides an essential input to the subdivision of the insurance period into different phases of measurement. Modelling the weather index on the crop model should guarantee the accuracy of the index in terms of correlation with the actual crop data; the more it mirrors the actual behavior, the better it works as yield proxy.

3.2.1.3. Hazard assessment and probability appraisal

During this phase, insurance experts study the behavior of the weather variable identified (e.g. rainfall), generate models to track the expected frequency of that hazard and study its spatial resolution (i.e. level of covariance) in order to account for the field level variations in the pilot area.

To understand the probabilities associated with the risk into account, experts generally consider historical datasets to build a probability distribution of the indexed parameter and thus predict a set of possible future events. However, this approach presents several significant flaws. Two key issues are the limited availability of historical data in some areas of the globe (especially those that need the most an index insurance) and the low quality with which they might have been recorded due to obsolescent technology. Moreover, major but rare events occurred in the past can distort the likelihoods, whereas what did not happen is not considered at all. In order to overcome these limits and fill in the gaps, historical dataset are combined with satellite data, private weather data[46] and known factors that might influence the weather variable into account: this allows elaborating

[46] Private parties who own weather stations in the area of interest, may share these data on a for-profit basis, that is by selling them not just for WII purposes, but also to clients such as newspapers, input suppliers, etc.

simulations that are more trustable. Even when available data seem to be reliable enough, interviewing farmers and other experts may provide information that, despite the lack of accuracy, is precious to validate or enrich historical detections.

These assessments should result in the identification of the so called "exceedance frequency curves", that is, the whole range of probabilities for different magnitudes of weather events. These curves, which describe the probability that various loss levels will be exceeded, represent the basis upon which insurers estimate their chances of experiencing different levels of loss.

3.2.1.4. Vulnerability assessment

Aim of this phase is the quantification of the potential financial impacts of an adverse weather event on farmers, for example on their income, investments, employment and debt. Also in this case, it might be useful to involve in the assessment process both experts and farmers in order to find out the number of vulnerable districts, their production averages in the recent past, the factors that may increase vulnerability, how groups' income levels have been affected as a consequence of already suffered weather events and any other relevant information that helps drawing clear vulnerability profiles of the districts involved.

3.2.2. Pricing the contract

Based on the qualitative and quantitative results of the previous assessments, the insurer sets the price of the insurance, or rather the amount of the premium. It reflects the probabilities of distributing payouts, which are in turn driven by the probabilities of hostile behavior of the indexed weather variable.

Many elements contribute to make it demanding the definition of a workable price: first of all the pressure to deliver a quality coverage at a low price, fair to both households and insurers, thus making index insurance affordable by the poorest, who also need it the most. Secondly, as already addressed in the previous paragraphs, establishing likelihoods implies a great deal of uncertainty due to the insufficient evidence generated by the rarity of some events and the lack of historical data[47], partially overcome by satellite figures and cooperation of farmers and experts. Lastly, price-setting follows the negotiations among insurers, buyers and reinsurers, each one with perceptions regarding future events that, despite the scientific assessments, may differ from those of the others due do the uncertainty variable that characterizes climate events.

There are several ways to address the price-setting issues: the sharing of transparent documentation, the installation of more advanced weather stations, the understanding of links between different climate systems, would reduce uncertainty for all the parties involved and keep prices realistic. Scaling up the contract, then, would help risk carriers (i.e. insurance and reinsurance companies), which would benefit from risk-spreading opportunities, risk aggregation and offsetting prospects, that lower returns' variability and foster the access to larger pools of capital, thus softening the scarce profitability typical of the early stages of coverage. In some other situations, climate is foreseeable enough to reduce the uncertainty component that drives prices up. This is the case of tropical regions, periodically hit by El Niño – Southern Oscillation (ENSO), which entails strong and correlated global patterns such as droughts in some geographical zones and abundant rainfall elsewhere. In Africa, for example, ENSO is such that a dry season in the East is often associated with a wet one in the South (La Niña), and vice versa (El Niño). Insurance companies should exploit complementary climate patterns like this one: by resorting to geographic risk spreading, that is, by developing programs that cover both the areas involved, they would significantly reduce their risk exposure since it would be very unlikely that a drought insurance contract, for example, pays out simultaneously in both regions[48].

Pricing methodologies are countless but, generally, insurance premiums include at least these three components:

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[47] Developing countries typically have at most 25-30 years of weather data, a time frame too short to reveal significant trends and allow the correct forecast of catastrophes.

[48] M. Vicarelli, *Intertemporal and geographic risk spreading*, New York: IRI, Columbia University, 2008

- *Expected loss*: average contract payout in any given season, derived from the combined consideration of frequency, severity and extent of weather-related losses (pure risk).
- *Risk margin*: amount charged to increase the insurer's capital reserves and account for the possibility of distributing payouts above the average. Their existence is explained by data uncertainty in terms of (un)detected trends and missing values.
- *Administrative costs*: operational costs incurred by the insurer to run the business, including taxes, commissions, contingency allowance and reinsurance fees (if any). Differently from the most common insurance contracts, WII premiums do not have to account neither for loss assessment nor for individual risk assessment costs, that contrarily show up when writing common agricultural policies, which consequently require excessive premiums for most farmers.

Basing on this, we can first identify in the gross insurance premium a "pure" or "technical" component, which only accounts for expected loss:

Pure (or technical) premium *=*

Expected Losses / Exposure units

Consequently:

Gross insurance premium

Pure premium + risk margin + administrative costs

or

*Gross premium rate * (insured amount per hectare * number of hectares)*

Farmer's real premium =

Insured total premium * (100%-%subsidy[49])

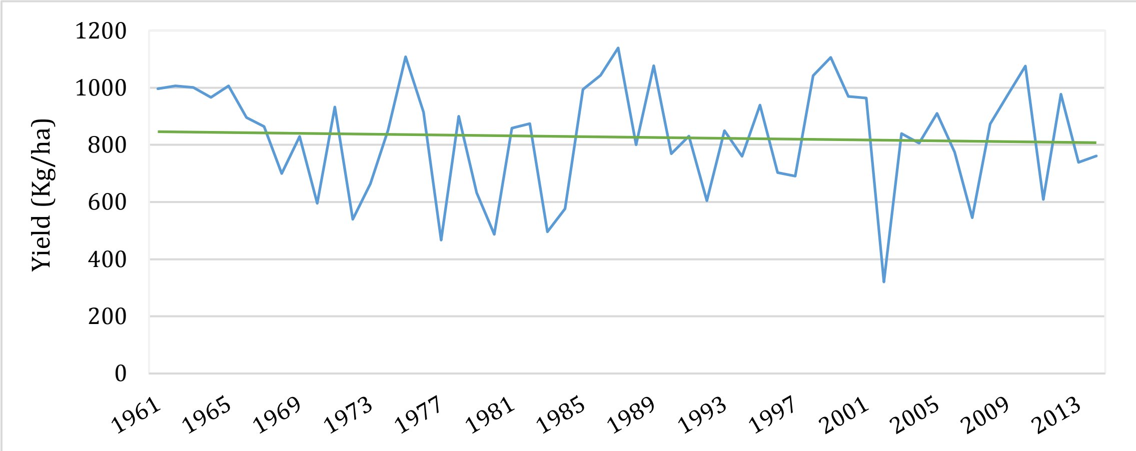
[49] In many vulnerable Countries, a percentage of the insurance premium is subsidized by the government or by NGOs. This implies that only the remaining percentage is in charge of the insured farmer.

An example of this is provided in paragraph 4.2.4, based on real premiums applied in Senegal.

But how are pure premiums calculated? As mentioned at the beginning of this paragraph, their utility consists in covering the economic losses in which the insurance company will incur (that is its business!), so they have to reflect the probability of paying payouts, which is in turn driven by the probability of happening of the adverse climate event and the related severity. To do this, insurance companies resort to actuarial mathematics to determine the expected economic loss and a measure of how much their actual loss can deviate from the expected one. In case of natural events and almost all the other insurable events, their probability cannot be determined *a priori* (that is the case of a die roll or a coin flip, where the possibilities are limited and known) because their happening is influenced by countless factors and combinations, resulting in highly variable outcomes. In order to "extract" the probabilities associated with climate events, the loss frequency and the related magnitude, it is necessary to start by analyzing the historical datasets related to the weather variable in object (rainfall in this case) and its impact on crops. They are then summarized in a probability density function that shows the severity of possible events against their frequency and probability. This tool is useful to observe the expected economic loss (mean) and losses dispersion around the mean (standard deviation), which gives insights about how much the actual loss can deviate from the expected one.

The following example shows how to apply these concepts to compute the pure premium that an insurance company should require to insure against groundnuts' exposure to drought risk in Senegal. The choice of this crop is not casual; peanuts' yield, in fact, is highly correlated to rainfall amount (as it will be proved in paragraph 4.2.2), a condition that ensures that in case of groundnuts' loss, it is highly probable that it is due to rainfall deficit.

Chart 3.2 – Groundnuts Yield (kg/ha) 1961-2014



Source – FAOSTAT database - http://faostat3.fao.org/download/Q/QC/E

As the chart shows, in 22 years out of 53, groundnuts' yield has been below the average. The following table summarizes the yield, the loss and the economic value of that loss (only economic losses are insurable risks) in each of the 22 years.

Table 3.3 – Years of groundnuts' loss and related amount

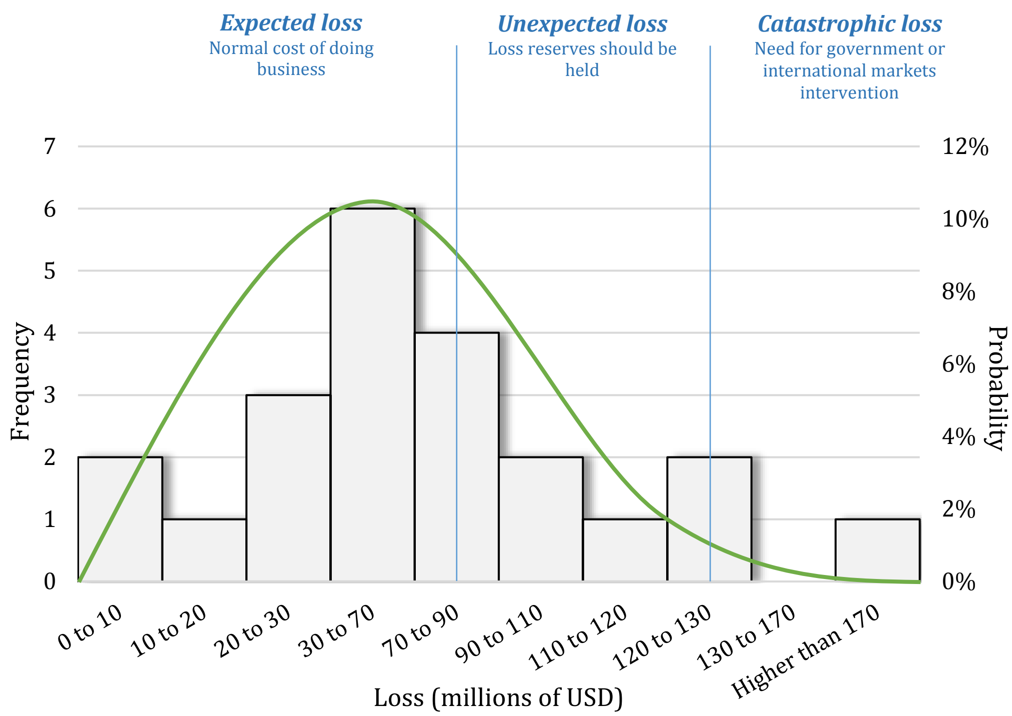
Yield average (1961-2014)	828,24		
Years when loss occurred	**Yield (kg/ha)**	**Loss (kg/ha)**	**Loss (USD millions)**
1968	700,2	128,04	45,04
1970	596	232,24	81,70
1972	540,1	288,14	101,37
1973	664,4	163,84	57,64
1977	466,3	361,94	127,33
1979	632,4	195,84	68,90
1980	486,6	341,64	120,19
1983	495,5	332,74	117,06
1984	577,1	251,14	88,35
1988	800,2	28,04	9,86
1990	768,7	59,54	20,95
1992	604,6	223,64	78,68
1994	760,1	68,14	23,97
1996	702,7	125,54	44,16
1997	691,3	136,94	48,17
2002	320,4	507,84	178,66
2004	806,4	21,84	7,68
2006	774,9	53,34	18,76
2007	545,5	282,74	99,47
2011	609,3	218,94	77,02
2013	739	89,24	31,39
2013	761,8	66,44	23,37

In order to build the probability density function, we identify how many years – out of 53 – a loss of a certain severity has occurred. For ease of reading, the losses have been grouped into 10 intervals, each one characterized by an average loss. Their frequency is then divided by 53 to obtain the annual probability of loss (or drought, given the high correlation). Table 3.4 and chart 3.5 show the results.

Table 3.4 – Loss average (USD), frequency, probability, mean and dispersion.

Interval of loss (USD millions)	Loss average in USD millions (Xi)	Drought Frequency out of 53 years	Drought annual Probability (Pi)	$Pi*(Xi - \mu)^2$
0 to 10	8,77	2	3,77%	13,56
10 to 20	18,76	1	1,89%	1,52
20 to 30	22,76	3	5,66%	1,40
30 to 70	49,22	6	11,32%	52,27
70 to 90	81,44	4	7,55%	217,69
90 to 110	100,42	2	3,77%	199,37
110 to 120	117,06	1	1,89%	150,55
120 to 130	123,76	2	3,77%	347,98
130 to 170	0,00	0	0,00%	0,00
Higher than 170	178,66	1	1,89%	429,79
Total		22 years out of 53	41,51%	1414,13
Annual Mean $\mu = \Sigma (Xi*Pi)$	27,73	= EXPECTED ANNUAL LOSS		
Variance $\sigma^2 = \Sigma Pi (Xi - \mu)^2$	1414,13			
Standard deviation $\sigma = \sqrt{\sigma^2}$	37,6			

Chart 3.5 – Probability density function of groundnuts' drought-related loss.



The shape of this distribution shows that the droughts that happen with higher frequency are also the least severe in terms of impact on groundnuts' yields, while catastrophic losses occur much more rarely (tail events).

According to this dataset, the expected annual loss of groundnuts is USD 27,73 million. Assuming a 70% coverage, a single Senegalese insurance company may incur in USD 19,41 million annual expenses to pay indemnities for groundnuts' losses (assuming that all Senegalese groundnuts' fields are insured and equally exposed). By increasing the sample, the actual loss suffered by the insurer approaches the expected one, thus reducing the objective risk (measured by the standard deviation).

Considering an average of 788.120 hectares of groundnuts planted (which coincide with the units exposed to drought risk), the pure premium is equal to the insurer's expected annual loss divided by the number of units exposed:

$$\text{Pure premium} = \frac{\text{Insurer's Expected Loss}}{\text{Exposure Units}} = \frac{19.411.468{,}61\ \text{USD}}{788.120{,}00\ \text{Ha}} = 24{,}63\ \text{USD per Ha}$$

This value is then loaded with unitary risk margin and administrative costs in order to obtain the gross insurance premium per hectare.

$$\text{Gross insurance premium} = \text{Pure premium + load} = \frac{\text{Pure premium}}{\text{1- Expense ratio}} = \frac{24{,}63}{1 - 0{,}4} = 41{,}05\ \text{USD per Ha}$$

The assumption of uniform exposition of groundnuts to drought risk is obviously strong, since the Northern regions of Senegal are much more exposed to rainfall shortage than Southern ones (see paragraph 4.2.2). This is only an illustrative example but, for completeness purposes, it is necessary to say that insurance companies charge higher premiums where crops are more vulnerable (the higher the loss probability, the higher the mean or expected loss, the higher the premium needed to cover it).

The law of large numbers is useful to insurance companies since it allows to charge premiums to cover losses before their happening. However, the infrequency and high variability of catastrophes is such that insurance companies cannot rely on the law of large numbers to prepare for those losses. To address catastrophe risk it is necessary to resort to higher layers, namely either the reinsurance companies (which cover a much larger geographic area and transfer risk to other insurers) or the international financial markets. In the latter case, the risk is transferred to investors by selling catastrophe bonds, contingent surplus notes, exchange-traded options, industry loss warranties, etc. Also the investors can take advantage from these securities, since they can benefit from a higher rate of return for the increased risk, and a more diversified portfolio (due to the non-correlation between financial markets and extreme climate events).

3.2.3. Index monitoring

For an accurate and reliable insurance coverage, the reference weather station should be placed close to the insured crops, a prerequisite that is more and more difficult to meet as the project scale gets larger. To avoid manipulation, the station should be managed by the national meteorological service (or a trustworthy private company), is required to meet international weather management standards (such as those issued by the World Meteorological Organization), should be automated[50] and subjected to periodic checks and quality controls. In case of shortage of weather stations, an alternative to the expansion of the local stations network – which would be the most efficient choice – is the *remote sensing*[51]. Given its tamper-proof nature, it is mainly adopted to validate ground detections but, occasionally, it is also usable to address a temporary lack of data ("occasionally" since satellite figures are not as accurate as ground-collected data and farmers may not trust the insurance company that estimates payouts basing on them).

Falling short to ensure that the distance between reference station and insured crops is such to guarantee a correct coverage, implies an increase in the spatial basis risk since the distance would increase the difference between what measured by the index and what actually occurred at crop level[52].

An exemplary case of blending of satellite and ground data is provided by LEAP (Livelihoods, Early Assessment and Protection), a software developed by the World Bank and the World Food Programme that uses both the types of data to monitor drought risk in all the Ethiopian administrative units, including areas without weather stations. Rainfall data are then converted into crop production estimates, which are used to build stress indicators of vulnerable people's livelihood and

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[50] Hellmuth M.E., Osgood D.E., Hess U., Moorhead A. and Bhojwani H. , *Index insurance and climate risk: Prospects for development and disaster management*. Climate and Society No. 2. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, 2009, p. 24.

[51] It consists in data from satellites that are available for large areas of the globe and in almost real time.

[52] The acceptable distance varies with the landscape homogeneity: generally, 20 kilometers is the maximum distance accepted for drought indices and 50 for those that track temperatures.

eventually used to esteem the financial size of the livelihood-saving interventions that these people would need in case of a weather shock.

3.3. Basis risk

Because of its nature, a constant constraint of index-based insurance products is the so called basis risk, which can be defined as the deviation of the farmer's individual yield loss from the district average or, similarly, the potential mismatch between the actual loss suffered by the insured parties and contract payouts (which are homogenous across the entire area covered by the insurance).

Basis risk can take several forms, for example a household experiencing loss but not receiving payout (or not enough), or payout being triggered without any loss suffered. On a general basis, it is possible to distinguish between three types of basis risk:

- *Product basis risk*: it occurs when there is no clear correlation between the indexed weather variable and crop losses, which may have been caused by other different factors. This is the reason why WII works better when adopted in areas with limited human intervention and to address severe meteorological events, which imply more widespread and consistent losses (see paragraph 2.3.2.).
- *Spatial basis risk*: it refers to local variations in the hazard occurrence in the surroundings of the reference weather station. This risk increases as the geological homogeneity of the areas covered decreases.
- *Temporal basis risk*: it is generated when there is temporal misalignment between insurance period's phases and crop's growth stage.

These shadows of basis risk make it clear that the effectiveness of Weather Index Insurance depends on how well yield losses match with the contract's underlying weather index. Therefore, WII is most likely to work where the weather hazard into account presents high covariance (e.g. droughts and floods), low frequency (contrarily, high risk frequency would drive premiums up, making WII unaffordable by the poorest) and close correlation with the local crop yield, thus causing homogenous losses.

Basis risk hampers the effectiveness of indexed products that transfer almost any weather-related risk, however it mainly concerns rainfall, which patterns present a higher degree of spatial and temporal variability compared with other meteorological events. On this purpose, one need only think to how different precipitation intensity or cumulative level could be where the reference weather station is and where crops are, even when the latter are reasonably close to the gauge. Hail, then, is even more localized that rain, reason why it is generally addressed through indemnity- and not index- based insurance products.

The issues listed up to now lead to the identification of the following measures to reduce basis risk: use index-based insurance when there is evidence of clear correlation between agricultural damage and adverse climate event, select regions which morphology does not imply significant weather variability, target single-cropping areas to reduce the variability of plants' response to the same adverse event, define the insurance period's phases in line with the plants' life cycle, augment the density of weather stations in the target geographical area[53] and engage debates among farmers, experts, agronomists and any other stakeholder to share relevant knowledge and make the index mirror reality. To completely eradicate basis risk, separate contracts should be drafted on indices measured at the various locations where the contract is implemented, a procedure that would be expensive and would wipe out one of the most attractive features of index-based insurances (i.e. low transaction and operative costs)[54].

[53] This would imply recording in the insurance contract more than one reference weather station. Keeping equal all the other contract features, this change allows to recognize payouts more in line with the actual losses suffered by smaller groups of farmers within the same insured area, since the incremental payments would reflect the local unit deviation below (or above) the trigger value. However, this comes at a cost: installation and maintenance of the new stations (that may be reflected in higher premiums) and slightly longer processing times to define group payouts.

[54] D.V. Vedenov, B.J. Barnett, *Efficiency of Weather Derivatives as Primary Crop Insurance Instruments*, Journal of Agricultural and Resource Economics, volume 29, issue 3, 2004, pp. 387–403

3.4. Summary of pros and cons of Weather Index Insurance

The following table summarizes the main advantages, disadvantages and challenges that characterize Weather Index Insurance.

Advantages	Disadvantages and challenges
No assessment of losses at farm-level, which are time consuming, complex and costly. Indemnity payment is only based on deviation from the index. **Rapid payout** thanks to the absence of field loss adjustment. **Low administrative and operational expenses** since there is limited client assessment and no need to mobilize skilled assessors to estimate individual losses. **Transparency**, which strengthens **trust**, because the policyholder has direct access to the information that define indemnity amount. **Address correlated risks** (droughts, floods), that traditional insurance products cannot insure with the same efficiency and rapidity. **No adverse selection**, which occurs when policyholders hidden information about their risk exposure, letting the insurance company wrongly assess the risk faced by the insured (information asymmetry). This does not happen with index insurance since it applies same insurance conditions to all the households in the reference area, regardless of the individual risk exposure. **No moral hazard**, which occurs when policyholder engage in hidden activities to	**Designing** the appropriate **index is a demanding task** in economic and temporal terms. **Technical expertise** is needed at different levels of the insurance drafting and implementation process (e.g. during the initial design of new contracts, in agro-meteorology, data analysis, etc.). **Crop-specific nature**, since the product is designed for specific crops, therefore farmers who practice intercropping may be excluded from WII or not fully satisfied. Only a **limited number of natural hazards** can be addressed through a WII. Where crop type or climate present complex dynamics and several factors affecting damages or losses (e.g. in humid zones or where disease is the dominant cause of loss), WII may not satisfy local risk management needs. **Limited options for different weather risks**. Most of WII products address drought risk, which is not necessary the most common and serious. It is necessary to design indices able to grasp more complex situations, such as the interaction of multiple chained risks (e.g. high temperature and consequent diseases). **Shortage of historical and real-time weather data** (in terms of both availability

increase their risk exposure, exacerbate physical losses and influence indemnity payment. Weather Index Insurance makes this practice useless (or deleterious) because all farmers in the reference area are treated equally, and physical phenomena are objectively observable and cannot be affected by farmers' behavior. **Low threshold of insurability** compared with traditional agricultural insurance. **Simple design**, easy to be shared with rural households within education programs. **Low premiums** make WII affordable by the poorest, who otherwise would not embrace this choice. **Facilitate access to financial services** by increasing farmers' creditworthiness thanks to the lower vulnerability to extreme weather events and the possibility to use WII as a collateral to obtain credit at better rates. In case farmers cannot afford paying premiums in cash, it is possible for them to buy WII coverage in exchange for their engagement in **risk reduction activities**.	and quality) in most of the developing countries. **Basis risk** represents a big disadvantage for both the parties: if a household experiences a loss but does not receive payouts (or not enough), he may be discouraged from purchasing the policy (farmers actually want full indemnity). If payouts are triggered without any loss suffered by the policyholder, the insurance company faces an excess of expenditures. **Integrity of reference weather stations**, which have to be automated and secure enough to prevent data manipulation, human error and tampering. Since it is a new product in developing countries, there is the **need for farmers and insurers education**, to let the former understand basic insurance principles and risk covered, and the latter receive technical assistance in product design and future developments. Most farmers have **low disposable income**, which explains why the majority of them buys the coverage through Insurance For Assets scheme.

As this summary suggests, Weather Index Insurance is on the right path to improve rural resilience against climate adverse events and, if climate science and indexation keep improving to address the whole spectrum of weather processes, index-based insurance is likely to become robust and efficient enough to foresee and face climate change, thus becoming a valuable instrument in communities' adaptation toolbox.

Chapter Four

Case study: the implementation of WII in Senegal. Background, numbers and key findings

The chapter opens with a short review of African Countries' exposition to droughts and floods, detrimental events especially for agriculture – the main economic activity on the Black Continent. The focus is then narrowed on Senegal, where weak infrastructures, sluggish economy and pronounced inequalities produce difficult living conditions, further exacerbated by climate change and severe environmental degradation. The combination of these circumstances is resulting in the high vulnerability of Senegalese people to external shocks and natural disasters, a scenario that makes Senegal a suitable Country where to assess climate risk and study the effectiveness of risk management strategies in building people's resilience to natural disasters. Following the analysis of the irregular distribution that rainfall shows in Senegal, the chapter proceeds examining the relationship between Senegalese main rainfed crops and their exposure (or non-exposure) to wet conditions. Based on this background and on the development status of Senegalese insurance system, the chapter closes with a detailed description of Weather Index Insurance "landing" in Senegal, the contract design, features, implementation process, actors involved and the results achieved in the last two years in terms of improved food security and better quality of life.

4.1. Reference context: the African continent

This paragraph discloses observed and projected extreme climate events that concern African Countries and their impact on human and environmental dimensions of the Black Continent. This overview helps building awareness regarding *where* risk mitigation strategies have been or need to be implemented.

Among the economic activities performed in Africa, agriculture is the one on which the majority of the population relies for its livelihood, employment[55] and the one that contributes the most to the exports of the continent[56], however it is the most vulnerable to climate-related catastrophes, especially in the sub-Saharan Countries. In particular, it has been estimated that climate impacts in Africa in 2100 will amount to 31.96% of Agricultural GDP (and 1.36% of total GDP), forecasts obtained by averaging 14 climate models[57].

This vulnerability is exacerbated by weak infrastructures, high price volatility and poor living standards, issues that inevitably worsen the coping ability of the hit communities.

According to the data recorded in the last century and the trends forecasted for the future, droughts and floods have been assessed as the major threats, with the former implying famine, death of cattle, soil salinization, and the latter landslides, disruption of the connection facilities and electricity supplies. Indirectly, both of them may also cause the spread of epidemic diseases such as malaria and cholera.

In particular, the monitoring of SMA and PDSI indices (see table 2.5 in chapter two) revealed that there is medium confidence in a general dryness increase, even if with regional variability: despite the continent-wide drought occurred between 1983 and 1984, since 1960s Horn of Africa, Southern Africa and Sahel have been the most hit areas, especially the last one. In Western and Southern Africa there has been a CDD increase in the late 20th century, with western Sahel leading the scores, whereas dryness conditions in Eastern Africa and Sahara have been obtained with low confidence due to limited data availability[58].

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[55] In Africa, 65% of employment is explained by agriculture.
West Africa Agricultural Productivity Program, official website of The World Bank: http://www.worldbank.org/en/topic/agriculture/brief/the-west-africa-agricultural-productivity-program [Accessed September 9, 2016]

[56] 50% of the value of African total exports is due to agriculture.
Mendelsohn et al., *Climate Change Impacts on African Agriculture*, Washington DC: World Bank, 2000.

[57] *Ibidem.*

[58] Trenberth et al., *Surface and atmospheric climate change* in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the IPCC Fourth Assessment Report*, Cambridge and New York: Cambridge University Press, 2007, pp. 237-336

Water represents a critical element in the fight against drought, however, there are at least three factors that hamper its accessibility and, thus, increase communities' sensitivity to this type of events. Firstly, the (un)availability of water storage infrastructures and the uncertainty regarding annual rainfall ability to fill natural reservoirs. Secondly, even where water results abundant, it may not be suitable for drinking and sanitation purposes, resulting in the reduction of freshwater usable by humans. A third element that menaces water supply is the high population growth rate in most of the African Countries, which implies an increase in the demand of water that consequently results in an even lower availability during droughts.

Confidence in rainfall and floods changes is lower than in droughts because of the lack of spatial and historical data. However, it seems that extreme events are correlated with El Niño phase of ENSO events (1982-1983, 1997-1998, 2006-2007)[59]. If in some areas floods bring devastating consequences (that is the case of Mozambique in 2000), some other regions may find floods providential: dry lands like Namib Desert and Sahara, for example, would be highly benefited by abundant water penetrating the ground and refilling aquifers and rivers basins, thus extending water availability to the dry season[60]. Considering future trend, population growth represents, once again, a critical element to take into account when projecting the number of people exposed to floods (and cyclones): their impact will almost certainly keep increasing based on this factor alone.

World Food Programme VAM field teams[61] quarterly provide updates regarding the impact of climate (and non-climate) events on food security in the most vulnerable Countries. Last issue, published on July 22, 2016, represents a valuable source of information about the current and forecasted weather situation in the African regions. The following pictures show the total rainfall as a percentage of the 20-year

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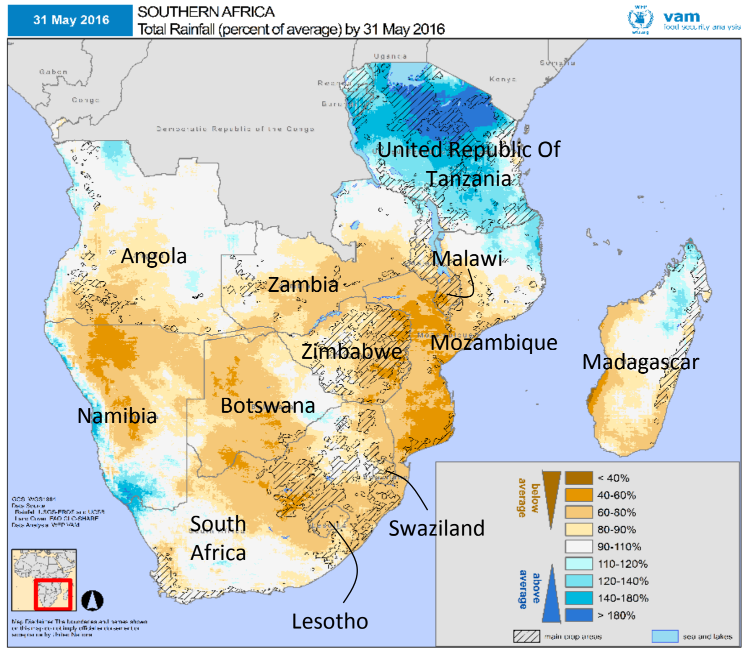
[59] Christensen et al., *Regional climate projections* in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the IPCC Fourth Assessment Report*, Cambridge and New York: Cambridge University Press, 2007, pp. 847-933

[60] Morin et al., *Flood routing and alluvial aquifer recharge along the ephemeral arid Kuiseb River, Namibia*, Journal of Hydrology, 2009, vol. 368, pp. 262-275

[61] Vulnerability Analysis Mapping is a work carried out by more than 150 analysts around the world to assess the food security status of a population before WFP's intervention.

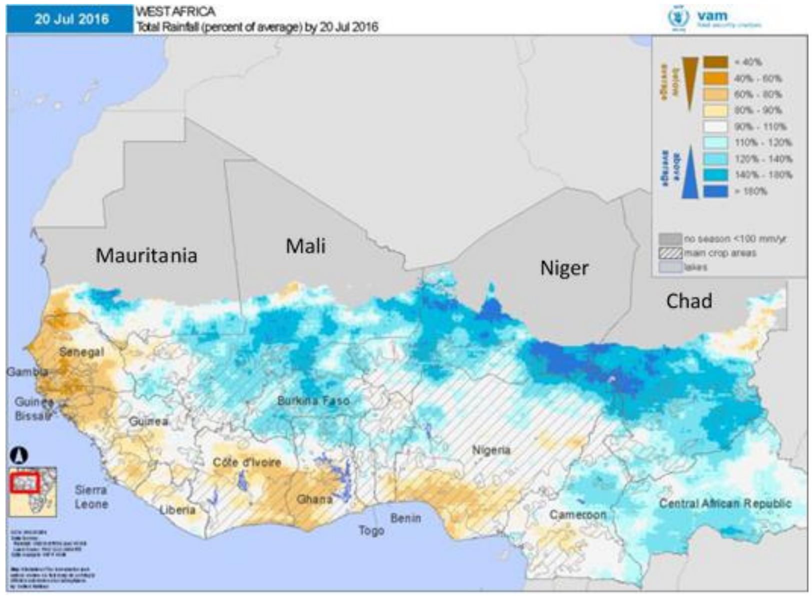
average, hashed patterns refer to main crop areas, brown shades indicate below average rainfalls and blue shades the above average ones.

Southern Africa



The region is suffering from a severe and 2-year long El Niño-related drought that has left 23 million people needing food assistance. The poor harvests are pushing up food prices, local cereals stocks are running out and currency devaluation is making imports too expensive, thus making Botswana, Namibia, Lesotho, Malawi, Swaziland and Zimbabwe declare the state of emergency. A deeper study reveals that in Madagascar the prolonged drought is causing low crop yields, especially in the south of the island, leaving millions of people hungry (despite the recent harvest) and thirsty (in some areas water consumption has dropped to 1 liter per day). Late start of the rainfall season, below-average and erratic rainfalls are also menacing production in Lesotho and Zimbabwe, particularly in the south. On the contrary, maize production in Zambia is expected to meet national consumption needs and, to guarantee this, the local government has restricted its export until the end of September. However, the food crisis is making maize price almost 50% higher than the five-year average.

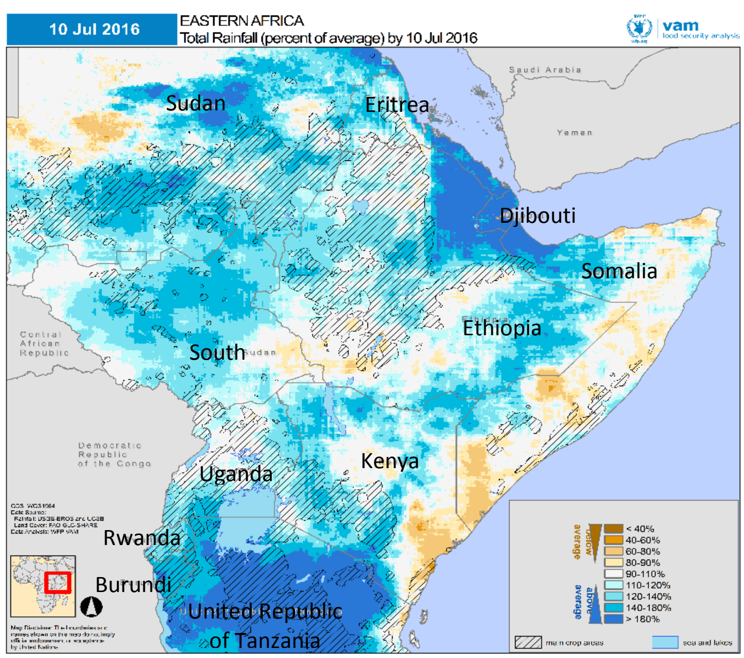
West Africa



Seasonal forecasts are optimistic for the Countries along the Sahel belt (eastern Senegal, Mauritania, Mali, Burkina Faso, Niger and Chad), largely untouched by El Niño and wetter than average. In contrast, Countries above and along the Gulf of Guinea (from western Senegal to southern Nigeria, through Gambia, Guinea Bissau, Sierra Leone, Liberia, Cote d'Ivoire and Ghana) are experiencing a season much drier than average, with significant impacts on crop production and water resources.

Despite the partial serenity related to weather conditions, conflicts are deteriorating security and humanitarian conditions in Lake Chad basin (Niger, Nigeria, Chad and Cameroon).

East Africa



El Niño is showing its effects also in this region, where persistent droughts are aggravating the food insecurity condition especially in northern Somalia, north-eastern Ethiopia (that in 2015 experienced the worst drought of the past 50 years), Djibouti, Eritrea,

Sudan, Uganda and coastal Kenya, while floods have affected other parts even in the same Country.
Conflicts in South Sudan are fuelling the fragile and tense conditions because of the disruption of agricultural production and market looting, events that are causing spikes of commodity prices (up to 80% for legumes and fuel) and strong devaluation of the local currency.

4.2. Weather Index Insurance in Senegal

4.2.1. Macro-economic scenario

Situated in the western part of the Sahel region, Senegal is one of the most stable African Countries from a political point of view, and it has significantly strengthened its democratic institutions since 1960, year that marked its independence from France.
However, in the past, Senegal has been victim of deep economic crises that concerned all the francophone African Countries, a situation that led Senegal devalue the local currency (the CFA Franc) by almost 50% in order to re-boost the national competitiveness. Together with structural adjustments and globalization policies, these initiatives worsened the local living conditions: government unable to meet the domestic demand for food, schools, transport infrastructures and health facilities, difficult access to drinkable water and sluggish job market have contributed to keep most of the Senegalese population in poverty conditions. According to the last updates issued by The World Bank[62], poverty here affects 46.7% of the population and, as in many other Countries of the Global South, it is mostly a structural and rural phenomenon (75% of the poor live in rural zones). The latter percentage is confirmed by the pronounced inequality (only marginally lower than the Sub-Saharan African average) and geographic disparity that afflicts the Country, where, on average, only one resident out of three lives in urban areas.

[62] *Senegal*, official website of The World Bank:
http://www.worldbank.org/en/country/senegal/overview [Accessed September 17, 2016]

Despite the strong macroeconomic performance registered in 2015, when Senegal GDP growth rate hit 6.5% (letting the Country be the second fastest growing economy in West Africa, behind Côte d'Ivoire), its erratic GDP pattern and recurrent shocks hamper the national progress and the way out of the poverty boundaries, with poverty incidence decreasing only by 1.8% between 2006 and 2011[63].

The difficult economic conditions are further exacerbated by the unfavorable investment climate, sluggish implementation of reforms in energy and agriculture sectors, poor management of exports, low diversification in income-generating activities, shortfalls that depress growth and increase the vulnerability of Senegalese economy to external shocks and natural disasters.

Nevertheless, looking forward in the medium term, the economic forecasts are promising: GDP growth rate should keep its high level, mainly driven by the service sector, especially financial services and telecommunications. Moreover, the end of Ebola epidemic will lift a huge weight from the national economy, the governmental program *Plan Senegal Emergent* (PSE) will attempt to increase Senegal productivity in public and private sectors and the roll out of the *Programme National de Bourses de Sécurité Familial* will be accelerated to enhance the welfare of the poorest.

4.2.2. Assessment of climate risk: relationship between rainfall exposure and main rainfed crops.

Agriculture is important for Senegal as it is for the whole Africa: it explains 20% of national GDP, employs 60% of local workforce[64] and is essential to guarantee food security. Encouraging agriculture and consequently reducing national dependence on international food supplies, in fact, means protecting Senegalese population against fluctuation of international food prices and unfavorable exchange rates that hamper imports, but it also gives the possibility to extend exports, create jobs and

[63] *Ibidem*.

[64] S.P. D'Alessandro, A.A. Fall, G. Grey, S.P. Simpkin, A. Wane, *Senegal - Agricultural sector risk assessment*. Agriculture global practice technical assistance paper, Washington, D.C.: World Bank Group, 2015, p. 71

generate more income. However, agriculture is a risky activity since it depends on weather, probably the most uncertain and incontrollable of the variables. Moreover, being positioned in the western part of the Sahel region – where rain is scarce and unreliable – Senegalese rain fed crops (98% of the total) face harsh times. The situation is further worsened by climate change and variability – which aggravate rural households' exposure to weather risk – along with population growth and foolish exploitation of natural resources, causes of severe environmental degradation.

Farming activities are highly influenced by rainfall, which in Senegal shows an erratic pattern in both spatial and temporal terms. A significant spatial difference can be detected between north and south: the most northern departments, particularly in Saint-Louis region – when annual precipitation barely exceeds 300 mm, suffer from an arid climate that makes commercial crop production only sustainable through recourse to irrigation. Average rainfall level increases southwards reaching its peak in Sedhiou region, where yearly rainfall exceeds 1000 mm and rainfed agricultural crops are far more intense thanks to the wetter conditions.

The following charts (figure 4.1) confirm the spatial gradient from north to south based on rainfall data in 2015[65].

The reference rainfall data derive from the CHIRPS[66] rainfall estimate, produced by the Climate Hazards Group, at the University of California, Santa Barbara. The Vulnerability Analysis and Mapping department at World Food Programme has developed a data visualization platform to monitor, assess and compare agricultural seasons' performance across countries and years.

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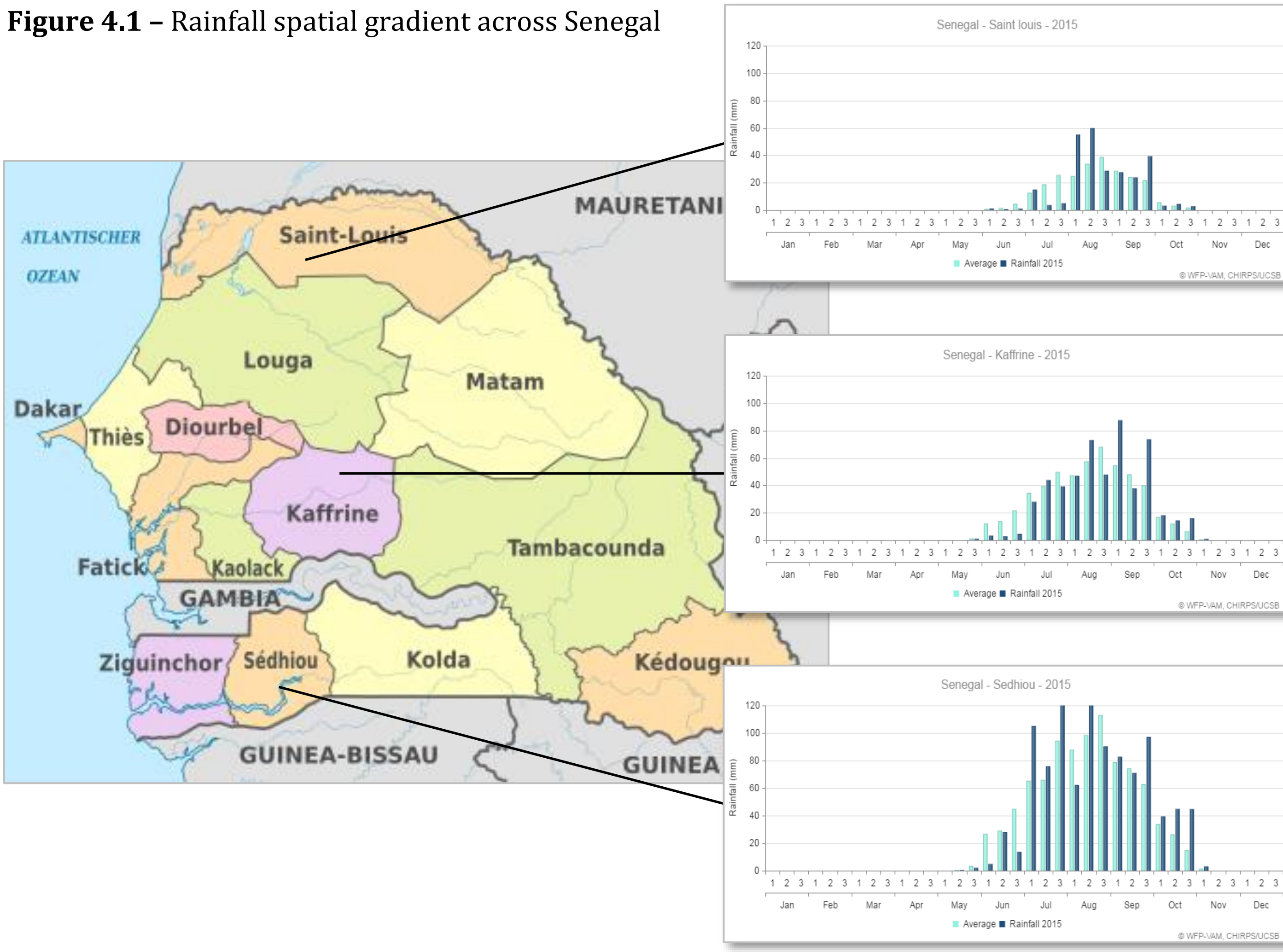
[65] Months, on the X-axis, are divided into three decades each. The Y-axis measures the millimeters of rainfall. Light blue bars show the long term average (20 years, 1994-2013) and dark blue bars show the rainfall amount registered in that specific decade.

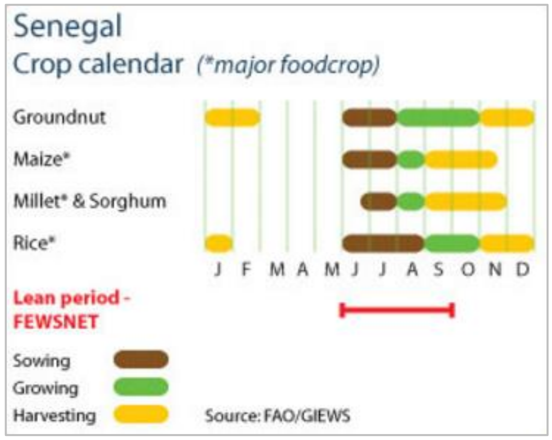
[66] CHIRPS stands for Climate Hazards Group InfraRed Precipitation with Station data. It is a quasi-global rainfall dataset with more than 35 years history, and it incorporates satellite imagery with local weather stations data to create time series for trend analysis and seasonal drought monitoring.

Figure 4.1 – Rainfall spatial gradient across Senegal



As these charts show, it is possible to clearly distinguish a dry season that ranges from November to late May, with near zero precipitation, and a rainy season that runs from June through October. This implies a single cropping season that begins with the planting in June and ends between September and November, when the main harvests are done. Figure 4.2 shows the sowing, growing and harvesting seasons of the major crops cultivated in Senegal.

Figure 4.2 – Senegal crop calendar



The spatial pattern of increasing annual average rainfall from north to south is a key point to explain higher annual average harvests in southern regions rather than in the north, however rainfall is not the only determinant: onset of rainy season, precipitation distribution over crops' life cycle, soil moisture, temperatures, inputs supply, play an important role in determining annual yields. A deeper analysis of the correlation between average rainfall and average yields in different departments, in fact, demonstrates a correlation coefficient (Pearson coefficient) not very close to the unit, meaning that further elements besides rainfall amount affect the harvests. In particular, the coefficient is quite strong for groundnuts and millet (0.84 and 0.83 respectively[67]) and weaker for sorghum and maize (0.75 and 0.72 respectively[68]). The R-squared pattern is the same, close to 0.7 for groundnuts and millet, lower for maize and sorghum (for which still more than 50% of yield variation is explained by rainfall variation). This provides clear evidence of the existence of basis risk, that is imperfect correlation between the climate variable tracked (rainfall) and farmers' yields. Table 4.3 shows these results, obtained in 2009 by the World Bank thanks to Meteorological Department Rainfall Data and DAPS Yield Data.

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[67] *Index-based Crop insurance in Senegal*, The World Bank, 2009, p.27

[68] *Ibidem.*

Table 4.3 - Relationship between Departmental Average Yields (1986-2007) and Average Rainfall (1986-2007) from North to South Senegal.

Latitude N-S	**Average Precipitation**	**Average Yields 1986/87 to 2006/07 (kg/ha)**			
Department	**1986-2007 (mm)**	**Groundnuts**	**Millet**	**Sorghum**	**Maize**
Dagana	213	393	229	460	-
Louga	287	504	184	257	600
Linguère	367	616	380	425	525
Diourbel	483	585	517	475	358
Bambey	479	564	522	571	454
Bakel	530	911	879	852	1,157
Thiès	427	532	459	497	561
Mbour	476	497	501	534	600
Kaffrine	586	945	771	879	1,220
Foundiougne	617	1,153	813	807	1,395
Nioro	762	1,039	912	1,034	1,501
Tamba	704	1,052	833	968	1,308
Kolda	1,021	1,219	898	885	1,430
Sédhiou	1,062	1,037	834	810	1,192
Pearson correlation		0.8404	0.8295	0.7522	0.7283
R Square coefficient		0.7062	0.6881	0.5658	0.5305

In temporal terms, rainfall patterns present a high variability also year-to-year, particularly in the northern arid departments in Saint-Louis and Louga, where the precipitation variation coefficient around the annual average reaches 45%. The variation coefficient decreases southwards, settling around 35% in central regions and 25% in the south[69].

Shifting the focus to Senegalese crop production, the World Bank database provides precious indicators regarding the Country's current status and its development over the last 50 years[70]. In particular, according to the latest agricultural census (2014),

[69] Direction de la Météorologie Nationale: http://www.anacim.sn/ [Accessed September 18, 2016]

[70] *World DataBank - Senegal*, official website of The World Bank: http://databank.worldbank.org/data/reports.aspx?source=2&country=SEN [Accessed September 16, 2016]

in Senegal there are 8.9 million hectares of agricultural land (which is arable land, under permanent crops and under permanent pastures), that correspond to 46.3% of the total land area , and 3.25 million hectares of arable land (that includes land defined by the FAO as land under temporary crops, temporary meadows for pasture, land under market or kitchen gardens and temporarily fallow land), that correspond to 16.8% of the total land area. Both the percentages have been decreasing since 2009, when the highest peak ever was reached (table 4.4)

Table 4.4 – Land area

Indicator name	2009	2010	2011	2012	2013
Land area (million hectares)	19,253	19,253	19,253	19,253	19,253
Agricultural land (million hectares)	9,538	9,508	9,015	9,015	8,918
Agricultural land (% of land area)	49,54	49,38	46,82	46,82	46,32
Arable land (million hectares)	3,88	3,85	3,35	3,35	3,25
Arable land (% of land area)	20,15	20,00	17,40	17,40	16,88
Permanent cropland (% of land area)	0,30	0,30	0,34	0,34	0,35

Source: The World Bank – World Development Indicators – Aug. 2016

Currently, only 2% of cropped area benefits from irrigation (including land irrigated by controlled flooding), meaning that the remaining part is rainfed and hence exposed to droughts and floods. Table 4.5 presents the main rainfed crops of Senegal: in 2013, groundnuts – grown both as cash and as food crop[71] – have been the most harvested, accounting for more than 37% of total cultivated area, followed by millet (34.7%) – the most drought resistant together with sorghum– and maize (7.4%) – largely used for animal feed and commercial starch production – data that are close to confirming the long term average[72]. Cowpeas – mainly a forage crop – are usually

[71] Cash or commercial crops are agricultural crops grown for sale to realize extra income (e.g. cocoa, coffee, cotton, sugar cane). Food crops are cultivated mainly for the subsistence of the producer's family (e.g. rice, maize, millet).

[72] *FAOSTAT – Crops Production – Senegal,* official website of the statistic division of FAO: http://faostat3.fao.org/browse/Q/QC/E [Accessed September 19, 2016]

intercropped with millet although they are harvested in a much smaller percentage of the cultivated area (5.6%).

Table 4.5 – Main crops in 2013 by cultivated area

Crop	Area Harvested (Hectares)	% of total cultivated area
Groundnuts (with shell)	769.803	37,4%
Millet	714.208	34,7%
Maize	151.450	7,4%
Sorghum	140.000	6,8%
Cow peas, dry	114.361	5,6%
Rice, paddy	108.227	5,3%
Seed cotton	32.000	1,6%
Cassava	22.115	1,1%
Sweet potatoes	1.500	0,1%
Total	2.053.664	100%

Source: FAO – Production Statistics – Crops, Crops Processed – Aug. 2013

As mentioned, being rainfed means being more exposed to adverse climate events. In order to limit the losses deriving from rain shortage or excess, the consideration of precipitation spatial gradient drives the decisions regarding crops positioning across Senegalese territory according to the crop's specific water needs. For example, to be of good quality and, therefore, economically viable, millet seasonal rainfall requirements amount to 450-500 millimeters and groundnuts' ones reach 600 millimeters. This implies that they firstly concentrate in central Senegal, especially in Kaffrine and Kaolack regions (therefore called "Groundnut Basin"), then in the western and southern departments, where water supply is much higher.

In terms of crops' yields, no significant growth trends can be detected over the past 55 years for any crop type, with the exception of paddy rice, which ascent trend began around 1980 with an average yield of 1000 kilograms per hectare and that, according to the last measurements (2014), has quadrupled, now exceeding 4000 kg/ha (see yellow line in chart 4.6), an increase due to the higher portion of rice crops that benefit from irrigation and advanced technologies[73].

A second crop which yield figure demonstrates relevant alterations, especially in the recent past, is maize. Up to 2002, its average yield has barely exceeded 1000 kilograms per hectare, however, in 2003-2005 and 2008-2010 it has risen, respectively, by 250% and 85%, results that can be partially explained with the extension of irrigation systems. Nevertheless, it seems difficult to identify the reasons behind maize yields' peak in non-irrigated areas, even because these two slots were not characterized by significant positive rainfall anomalies (with the exception of July 2005[74]). For this reason, it is gaining foothold the hypothesis of over-reporting of maize harvests in those two time slots. On the other hand, the last 4 years have seen the decrease of maize yields, due to adverse weather conditions (negative rainfall anomalies) registered in the critical phases of maize's crop cycle[75] (or, more generally, higher variability in seasonal rainfall).

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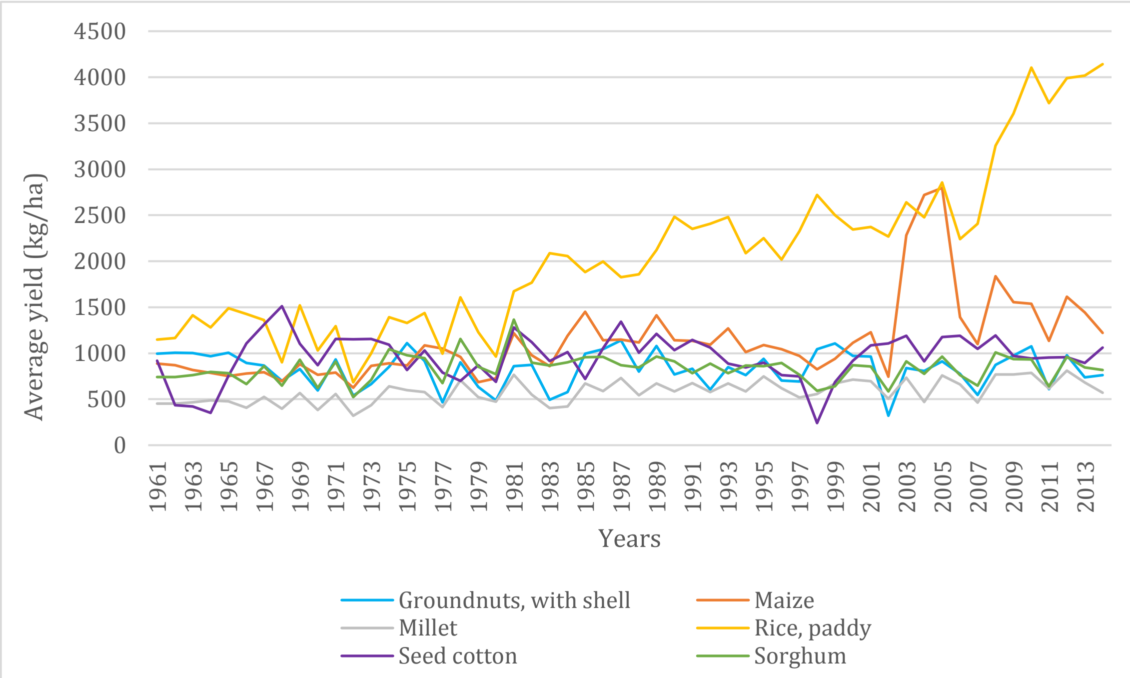
[73] DAPSA - Direction de l'Analyse, de la Prévision et des Statistiques Agricoles. http://www.dapsa.gouv.sn/ [Accessed September 20, 2016]

[74] Agro-climatic WFP data, World Food Programme - department of Vulnerability Analysis and Mapping (VAM)

[75] Ibidem.

Chart 4.6 – Average yields of Senegal' major crops.



Source – FAOSTAT database - http://faostat3.fao.org/download/Q/QC/E

By observing the chart from a larger perspective, it is possible to detect two major and generalized yields fall in 2002 and 2007. The first event, caused by an early season drought, drastically cut the harvests of almost all rainfed crops, excluding cotton seeds, which have an excellent water holding capacity. The most affected crops were groundnuts and maize, that respectively delivered only 37% and 66% of the 20-year average, followed by sorghum (67%) and millet (82%)[76], percentages which combination caused a national catastrophe. In economic terms, this drought caused a loss of almost USD 50 million[77]. Less severe was the outcome of 2007 early season drought, combined with short supplies of both fertilizers and improved seeds.

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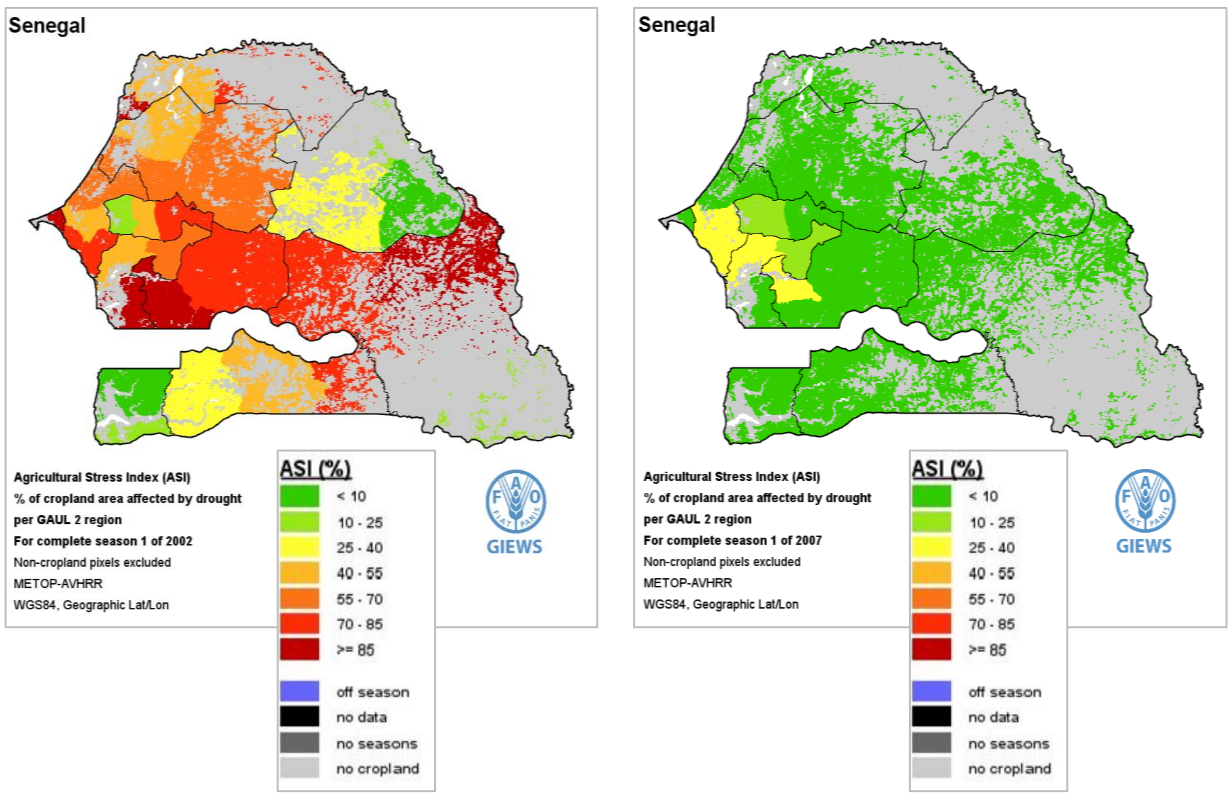
[76] Ibidem.

[77] S.P. D'Alessandro, A.A. Fall, G. Grey, S.P. Simpkin, A. Wane, *Senegal - Agricultural sector risk assessment*. Agriculture global practice technical assistance paper, Washington, D.C.: World Bank Group, 2015, p. 71

Figure 4.7 shows the annual summary of the Agricultural Stress Index (ASI) measured in Senegal during those two difficult years (2002 and 2007, the worst since the beginning of the third millennium)[78]. This index measures the percentage of cropland affected by drought; the calculation is based on 10-day satellite data of vegetation and surface temperature from the METOP-AVHRR sensor.

Figure 4.7 – ASI% in 2002 and 2007



4.2.3. Agricultural insurance system

In front of such a scenario, adopting risk management strategies becomes essential to contain (or reduce) vulnerability to climate risk and keep protecting national food

[78] FAO's Global Information and Early Warning System (GIEWS), Earth Observation, Senegal, ASI Annual summary:
http://www.fao.org/giews/earthobservation/country/index.jsp?lang=en&code=SEN# [Accessed September 22, 2016]

security. Income diversification is the most common approach, but agriculture is by itself a diversified activity since different crops, each with its cycle and sensitivity, are planted simultaneously in the available land (often *patches* of land). However, this line of action may not be sufficient to guarantee a stable food supply, in fact three quarters of Senegalese rural people does not manage to produce enough food to meet the minimum requirements of their family[79]. Investing only in crops diversification may limit farmers' opportunities to also invest in riskier activities, produce higher profits and eventually expand their productive capacity. Moreover, access to financial markets is an essential prerequisite to allow a truly diversified approach and, therefore, reduce farmers' vulnerability to shocks, yet the few guarantees that people have in poor Countries impede such access.

Together with risk mitigation and risk coping strategies, risk transfer is a powerful approach to address weather-related agricultural risk. In particular, the statistical approach on which insurance policies rely allows transforming households' future uncertainty (regarding crops' risk to be hit by adverse events) into income predictability.

Senegalese insurance industry is administered by the *Code d'Assurances*, established by the *Conference Interafricaine des Marches d'Assurance* (CIMA) on 15 February 1995. The latter, which co-operates with the insurance regulatory authorities to supervise insurance companies in signatory Countries in Francophone Africa, is in charge of approving the introduction of new insurance products in the domestic market. Therefore, any new agricultural or livestock insurance planned to be launched in Senegal has to first be ratified by CIMA, including Weather Index Insurance[80].

Studies carried out at international level highlight the higher efficiency in the implementation of agricultural insurance when this is managed by private companies. However, where insurance market is at a nascent stage and

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[79] *Ivi*, p. 68

[80] *La CIMA*, official website of Conference Interafricaine des Marches d'Assurance: http://www.cima-afrique.net/fr/node/990. [Accessed September 16, 2016]

infrastructures are not well developed, government (and, therefore, public sector) may play a crucial role in promoting a growth in this direction, for example by establishing an adequate legal and regulatory framework (as CIMA is for Senegal), enhancing data measurement and collection and making them publicly available, providing financial support for product design, testing and pricing, fostering education programs for both farmers (in order to increase awareness about the support that crop insurance may provide) and insurers (to generate expertise and independence) and funding reinsurance programs.

In Senegal, the agricultural insurance market moved its first steps in 1995, when the local government, acknowledging the importance of insurance, commissioned the Departments of Statistics and Agriculture and the *Direction des Assurances* to investigate on this subject. Eight years later, concrete actions were taken with the sponsoring of three major initiatives:

- EMAP agricultural risk study;
- Agricultural Insurance Feasibility Study;
- Establishment of a national, public-private owned, agricultural crop and livestock insurance company, CNAAS - *Compagnie Nationale d'Assurance Agricole du Senegal* (Senegal's private insurance companies were invited to jointly own the majority of the CNAAS).

In particular, CNAAS is the insurance provider for the products offered under the Risk Transfer component of the R4 Rural Resilience Initiative (illustrated in chapter one). Its founding in 2008 was part of a wider governmental intervention – aimed at supporting the agricultural insurance industry – which also included becoming shareholder of CNAAS and providing 50% insurance premiums subsidies on both livestock and crop insurances to make these products affordable by small farmers. Behind this intervention, there was the intention to address national economic and social needs, for example the stabilization of farm incomes, the maintenance of rural people, the promotion of ex-ante mechanisms to manage weather catastrophes, the incentive to agricultural development, for example linking insurance contracts with credit packages to boost investments in fertilizers, seeds and any technology capable of improving yields.

Since its creation, CNAAS has experienced significant and healthy growth: in march 2014, the holders of insurance policies issued by CNAAS were approximately 5,000 farmers and 1,500 breeders[81]; of course more scale is needed to reduce vulnerability of Senegalese rural population and shift their reliance from "ex post" disaster relief interventions to "ex ante" risk management initiatives.

CNASS' products portfolio contains a wide range of insurance options to cover life- (ensure microfinance institutions from the risk of death or total disability of the entrepreneur), livestock-, fishing- and crops- related risks. Among the policies designed to address the latter risk, there is the "*Assurance indicielle*" (index-based insurance)[82].

The index-based insurance in CNAAS' portfolio provides coverage against drought risk (based on rainfall data provided by Senegalese National Meteorological Service). The crops covered are maize and groundnuts, however the insurance can be extended to all the crops and areas according to the availability of statistical data and management infrastructures. The trigger value or threshold of the weather variable, which is the same over the entire zone covered, varies from one phase of the crop season to another due to the different sensitivity of the cultivation in the different phases of its cycle (as detailed in paragraph 3.2.1) . If, in each specific phase, the rainfall level is below the exit value associated with that phase, 100% of the harvest is considered lost, therefore the indemnity paid is maximum (according to the insured amount). However, the total indemnity payable to the policyholder over the entire cycle cannot exceed the total sum insured[83]. Here is an example of how the indemnity is computed:

Insured amount per phase (IA): 5000 XOF (West Africa CFA Franc)

Trigger level (TL): 350 mm

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[81] S.P. D'Alessandro, A.A. Fall, G. Grey, S.P. Simpkin, A. Wane, *Senegal - Agricultural sector risk assessment*. Agriculture global practice technical assistance paper, Washington, D.C.: World Bank Group, 2015, p. 73

[82] CNASS Assurance Agricole: http://www.cnaas.sn/produits.php [Accessed September 23, 2016]

[83] CNASS Assurance Agricole – Assurance Indicielle: http://www.cnaas.sn/assurindicielle.php [Accessed September 23, 2016]

Exit level (EL): 100 mm

Actual level of rainfall (calculated value of the index) (AR): 210 mm

Tick or incremental payout value per each mm below the trigger level= IA / (TL – EL) = 20 XOF

*Total payout: [IA / (TL – EL)] * (TL – AR) = 2800 XOF*

If rainfall level is below 100 mm, no incremental payment is done and the payout equals the insured amount (5000 XOF).

For CNAAS' contracts, the maximum insurance amount cannot exceed 200,000 XOF (~ 340 USD) per hectare. Over the three phases that compose the contract, the sum insured can vary – depending on the criticality of the specific phase – up to this total per hectare (further details in paragraph 4.2.4).

In order to make the policy financially viable for both the insurance company and the rural households, it is necessary to assess CNAAS' exposure to catastrophe and crop risk. This procedure is fundamental to estimate *pure risk* (derived from frequency and severity of weather-related losses) and *risk margin* (explained by data uncertainty), which are then charged to the premiums required to policyholders. For example, as noted in the previous paragraph, the insurance company should consider the variability of average crop yields across different regions, the higher exposure of northern regions to drought risk, the different water needs that characterize Senegalese staple crops (groundnuts, maize and rice are those that require more water to bear qualitative fruits, hence they deserve higher coverage from drought risk than sorghum and cowpeas), and start from these considerations to develop contracts that mirror the specific needs of the different insured areas. A portfolio crop risk assessment model called MARCS (Modèle d'Analyse des Risques de Cultures du Sénégal) has been developed to study the exposure of regional crops and support insurance companies in designing and pricing their indexed products.

Assuming that farmers' annual income per hectare is equal to the forecasted yield[84] multiplied by the expected retail price of the specific crop, minus inputs, production

[84] Considering rainfall as the only variable, thus not capturing the impacts that management practices, technology, etc. have on yields.

and (if any) financial costs, a loss occurs when the household realizes less than his average income. The insurance contract to which all the parties should aspire is deemed to be the one where indemnities and losses match in terms of timing and magnitude. That is, the one where the mitigating potential of a financial instrument realizes when it is needed the most.

Chapter 4.2.4 will illustrate the development status of this coverage among Senegalese rural households, combined with real data.

4.2.4. WII implementation and first results

After one year of piloting, in 2014 the Senegalese participants to the R4 initiative were offered the possibility to purchase the Weather Index Insurance. The offer began in five rural communities[85], each of them with an average of two clusters, where a cluster is a group of villages. The insurance policy issued to each cluster and the underlying index were designed based on the information gathered in one village per cluster (which is consequently called Index Design Village – IDV). The product thus structured was offered to all the villages in that specific cluster within a radius of 5 km from the IDV, a prerequisite that should guarantee the similarity of climatic and farming conditions.

Here are the main characteristics and stages of the contract designed for Senegalese farmers[86]:

- **Period of insurance and index:** the insurance period is split into two windows, each one characterized by a specific index:
  1st window - Early index: it addresses the risk of late or weak onset of the rainy season, which has impact on the seeding/establishment phonological phase.
  2nd window - Late index: it addresses the risk of early or weak conclusion of the rainy season, which may be harmful for the flowering and maturation phases.

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[85] They are fourth-level administrative divisions and represent the lowest tier of Senegalese government. Each rural community accommodates – on average – 25,000 inhabitants.

[86] R4 Rural Resilience Initiative – Quarterly report | April-June 2014, World Food Programme and Oxfam America

The two windows operate independently, contributing 50% of the payout each. Both the indices are calibrated according to the crop cycle and rainfall exposure of the reference IDV and both the early and the late index refer to data detected by NOAA ARC2 satellite, which addresses African Rainfall Climatology, in particular 10 km x 10 km resolution reflects rainfall patterns within each specific cluster.

- **Triggers and other parameters:** the rainfall levels below which indemnities start being distributed were established by interweaving more than 20 years of satellite rainfall observations, adverse years recalled by farmers, past cropping seasons and agro-meteorological knowledge of local population. Similarly, limit, tick and start/end date of the index were defined by insurance experts after discussing with local farmers.
- **Premiums:** regarding contracts purchased in exchange for labor (*Insurance For Assets* scheme), the premiums computed by CNAAS on the basis of expected loss, risk margin and administrative costs are equally subsidized by WFP and the Senegalese government (50% each). The intention is to invite more and more farmers pay directly in cash, a solution that would be made more accessible thanks to the appointment of Swiss Re, a global leader in reinsurance and climate change advocacy which contract with CNAAS helps safeguarding favorable contract terms and ensuring that CNASS' potential exposures are covered, thus keeping premiums accessible for policyholders.
- **Sum insured:** after studying production costs and proceeds, it was established that the maximum insurable sum per hectare had to be based on 50% of the expected revenue per hectare. This choice derived from the consideration that most farmers practice a low intensity production (low inputs – fertilizers, seeds, technology – and almost only family labor), which costs cannot be computed as clearly as it is possible to do with the output value. Moreover, if a severe rain shortage occurs in a critical phonological phase and damages crops causing a drop in value, the farmer has the possibility to recover half of the revenues initially expected, which are surely higher than the production costs. The total sum insured per hectare is split between the two windows that compose the insurance

period. For example, if the farmer expects that one hectare of groundnuts is worth 300,000 XOF, the total sum insured can be maximum 150,000 XOF per hectare, 75,000 in the first window and 75,000 in the second one.

- **Insurance process and actors involved:**
  1. Following field visits and the study of satellite data, the International Research Institute for Climate and Society (IRI) designs and maintains the index parameters.
  2. Based on the feedbacks of IRI and Swiss Re, CNASS develops and prices the insurance product.
  3. CNAAS drafts the policy documents and provides them to the *Fédération Yakaar Niani Wouli*, which intermediates between the Senegalese insurance company and farmers to assist participants' registration and address further issues.
  4. Regarding contracts purchased through *Insurance For Assets* scheme WFP pays to CNAAS 50% of the required premiums and Senegalese Government subsidizes the remaining half. Regarding contracts paid in cash by farmers, the *Fédération* intermediates between CNAAS and farmers for the premiums payment.
  5. La Lumière – a local NGO – rises the awareness of the targeted communities by delivering training sessions and offering support for the policy subscription.
  6. Once the registration is completed, farmers engage in IFA activities (building assets useful either for the community or at household level, such as irrigation systems, silos, small dams, vegetable gardens), organized and supervised by PAPIL.
  7. The first formal information to which farmers have access to check climate conditions are the weather forecasts issued by the National Meteorological Service. In case of uncertainty, high spatial gradient or when it is not clear if the rainfall registered by the reference weather station is below the trigger or not, insured farmers in the same cluster, who know the contract parameters, have the possibility to check the rain gauges planted throughout the territory

or interface with the *Fédération* to gain information on the existence of the conditions for the indemnity payment. In addition, it is now piloting an initiative to develop sms-based advisory services to all the insured farmers.

8. In case the index triggers, IRI provides technical satellite data and reference weather station data to CNAAS, which calculates payouts and transfers the related funds to the *Fédération*, which in turn distributes them to the policyholders.

Metrics from Senegal

Throughout 2014 and 2015, the R4 initiative expanded to many rural communities in Tambacounda, Kolda and Kaffrine, involving an increasing number of participants: during the first year, 6740 farmers were reached in Tambacounda and Kolda with one or more R4 components. Among them, 1989 rural households in Tambacounda purchased the Weather Index Insurance (risk transfer component) through the IFA scheme, thus engaging in risk-reduction activities. The average sum insured and premiums composition are in table 4.8. During that same year, the agricultural season was characterized by a wake onset of the rainy season that mainly affected the western districts of Tambacounda – mostly dedicated to groundnuts cultivation – therefore 299 farmers in the Koundiaw Souare cluster received a total share of USD 3,929 in payouts (USD 13.2 each)[87].

In 2015, the R4 initiative expanded to Kaffrine, reaching 12571 participants in the three regions, a high uptake that highlights the strong demand for risk management solutions. This year saw a noteworthy refinement of the reference index, namely the setting of a *daily* rather than *decadal* rainfall cap parameter to sensitize the capturing of rain gaps and be more accurate in tracking rainfall distribution, an addition that would have allowed capturing the dry spells occurred in 2014 that were not detected by the ongoing index. The number of policyholders rose to 3621: in particular, 3388 paid for the R4 insurance by working additional days (IFA scheme), the remaining

[87] R4 Rural Resilience Initiative – Annual report | January-December 2014, World Food Programme and Oxfam America

233 joined it through the PADAER project (promoted by the International Fund for Agricultural Development - IFAD). The average sum insured and premiums composition are in table 4.8. A prolonged negative rainfall anomaly from May to July made all locations in Tambacounda trigger payouts (except for the village of Woundoudou Amirou), whereas no clusters triggered in Kolda. It was later observed that the Tambacounda village that did not trigger suffered from climatic conditions similar to, if not worse than, those of the surrounding areas, a basis risk issue that was addressed by distributing as "indemnity" 10% of the sum insured. In total, 3334 farmers received payouts for the total amount of USD 80,969 (USD 24.3 each)[88]. Once the rainy season began, precipitation level was such that no village triggered during the second window.

The current year, 2016, has seen the increase of policyholders up to 6843 farmers throughout Tambacounda, Kolda and Kaffrine. Among them, 80 farmers chose to buy the insurance in cash, while further assessments regarding insured amount and premiums composition are still in progress.

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[88] R4 Rural Resilience Initiative – Annual report | January-December 2015, World Food Programme and Oxfam America

Table 4.8 – Progress of the R4 Risk Transfer component (WII) since its implementation in Senegal

2014	2015	2016
• **Regions**: Tambacounda	• **Regions**: Tambacounda, Kolda	• **Regions**: Tambacounda, Kolda, Kaffrine
• 1989 **farmers insured** through IFA	• 3621 **farmers insured**, of which 3388 through IFA and 233 through PADAER	• 6843 **farmers insured** through IFA
• Total **sum insured**: $200,776 (121,470,000 XOF) ~ $100,9 each	• Total **sum insured**: $592,888 (358,697,465 XOF) ~ $163 each	Further amounts are still being assessed, however comprehensive **premium rates** have been negotiated as follows: - Tambacounda: 6 – 10% - Kolda: ~6.39 % - Kougheul (Kaffrine): ~7.57%
• Total **premium amount**: $29,823 (18,043,394 XOF) of which 50% paid by WFP and 50% subsidized by Senegal government	• Total **premium amount**: $87,103 (52,697,146 XOF). - Under IFA $70,975, of which 50% WFP, 50% Senegal government - Under PADAER $16,128, of which $ 1,463 paid by farmers, the remaining paid by IFAD	
• **Number** of policyholders receiving payout: 299	• **Number** of policyholders receiving payout: 3334 (only Tambacounda)	
• Total amount of **payout**: $3,929 (2,244,302 XOF) ~ $13.2 each	• Total amount of **payout**: $80,969 (48,985,951 XOF) ~ $24.3 each	

The table below offers an example of how average gross insurance premiums are computed accounting for crops uniformity. With the exception of premium rates, which correspond to those currently adopted, other data only have an illustrative purpose.

Region	***Tambacounda***	***Kolda***	***Kaffrine***
District	Koussanar	Mampatim	Kougheul
Number of farmers insured	2000	2000	2000
Average area per farmer (ha)	4	3	4
Total area insured (ha)	8000	6000	8000
Sum insured per hectare (XOF/ha)	160,000	150,000	140,000
Total insured value	(8000*160,000)= 1,280,000,000	900,000,000	1,120,000,000
Premium rate	8,12%	6,39%	7,57%
Tot. premiums per district	(8,12% * 1,280,000,000) 103,936,000	57,510,000	84,784,000
Average premium per farmer (XOF)	(103,936,000/2000) 51,968	28,755	42,392

Many improvements are taking hold during this year: *first*, following field visits and meetings with partners and communities, the two insurance windows will be shifted onwards to better account for changes in the rainy season pattern. *Second*, starting this year and for the first time ever, R4 sponsors have begun testing climate services in Senegal as a supplementary component to manage (or reduce) climate risk. Thanks to the cooperation with two partners in Tambacounda and Kolda, the project aims at providing farmers with “sms-based weather forecasts and advisory services to assist farmers in making informed decisions regarding agricultural activity” [89] (e.g. decide which seeds would be better planting given the forecasts, and when), an

[89] R4 Rural Resilience Initiative – Quarterly report | April-June 2016, World Food Programme and Oxfam America

initiative that would help farmers prevent losses that may be caused by forthcoming adverse events and, therefore, strengthen their resilience. *Third*, many training programs for both local experts and farmers are being held throughout the R4 regions: the formers – partners of the R4 initiative – are being trained on the provision of advisory services, on rainfall data interpretation and index insurance design (necessary to become independent and get ready for future scale up of the coverage). Farmers, on the other hand, are being educated on insurance operating principles and on prototype indices, with the aim of increasing their awareness, communicating the WII potential and involving them in the identification of the index that better fits the weather and farming conditions they live in. *Ultimately*, more rain gauges are being installed in the areas covered by R4 to monitor precipitation distribution with greater accuracy and thus adjust for the basis risk.

4.3. Risk management: an essential instrument in the resilience toolbox

Risk transfer mechanisms, and in particular Weather Index Insurance, are only one component of the wider risk management framework needed to build resilience to climate change and natural disasters.

As mentioned in the first chapter, the R4 initiative counts on three other components, namely resource management through assets creation (*risk reduction*), microcredit and livelihoods diversification (*prudent risk taking*) and savings (*risk reserves*).

Studies and surveys conducted by the World Food Programme reveal that rural communities particularly value the risk reduction component since the tangibility of the assets built gives them real sense of the concreteness and effectiveness of the fight they are leading against climate risk. In Senegal, Ethiopia, Malawi and Zambia (the Countries where R4 is now present), thousands of meters of stone bunds are being created or reinforced to protect cultivated fields from sand and collect surface runoff; micro gardening activities (and related training sessions on how to manage a vegetable garden) are spreading throughout rural families to allow for a diversified diet while being self-sustainable; drainage systems to regulate and store runoff of rainfall water are being built to recharge groundwater when rain lacks. Reforestation, dams' reinforcement, distribution of seeds and farming tools, trainings on soil and water conservation and many other concrete actions are thickening the risk reduction component. Another tool that is proving to be successful in reducing climate risk is Food assistance For Assets (FFA) program, a cornerstone in WFP's resilience building plans since it addresses both the immediate needs of the most vulnerable (by distributing food, vouchers and cash transfers), and the urgency of resilience enhancement (by incentivizing the restoring of ecosystems, the rehabilitation of assets to reduce the impacts of climate shocks and so on). By January 2016, 1,084 metric tons[90] of food have reached 111,636 Senegalese farmers[91].

On the prudent risk taking side, the "warrantage" practice is taking hold, a financial mechanism whereby farmers have the opportunity to store the surplus production in cereal banks allowing the latter to use the stock as a collateral for loans; this would prevent farmers from selling the extra products soon after the harvest, when the need for cash is high but prices could be low. Once reimbursed the loan, cereal stocks are released, hopefully in August, the peak of the lean season (no stocks left and crops still to be harvested). Thanks to this initiative, an increasing number of farmers are accessing credit in exchange for the stocking of tons of cereals; only in the second quarter of 2016, 11,614 metric tons of rice, millet and maize have been stored in Kolda, allowing 75 rural households to access credit for 2,100,000 XOF (~USD 3,546)[92]. In addition, training is being delivered on microcredit principles, income generating activities and financial management (planning and budgeting) in order to raise awareness and engage the rural community in diversified and remunerative

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[90] Unit of mass equal to 1,000 kilograms.

[91] R4 Rural Resilience Initiative – Quarterly report | October-December 2015, World Food Programme and Oxfam America

[92] R4 Rural Resilience Initiative – Quarterly report | April-June 2016, World Food Programme and Oxfam America

activities. Weather Index Insurance plays an important role in supporting this component of the risk management framework since, as mentioned in the first chapter, it facilitates access to credit at better rates, serving as a collateral. The loan obtained thanks to WII, warrantage or microcredit solutions can be used to invest in seeds, fertilizers or technologies capable of improving the agricultural productivity.

Lastly, regarding the risk reserve component, the "Saving for Change" program launched by Oxfam America and implemented by La Lumière (the same NGO that delivers insurance trainings) is supporting saving groups in collecting funds and foodstuffs to be dispensed upon emergency requests. Only in Senegal, 650 saving groups are already active and have saved 62,235,235 XOF (~USD 108,600)[93]; many other groups can be found in Ethiopia, Malawi and Zambia, and they have already showed their utility in sharing out their funds in times of need or to face unpredicted shocks.

These concrete results, together with all the not-mentioned results achieved in Ethiopia, Malawi, Zambia, but also Kenya, Rwanda, Bangladesh and many other vulnerable Countries worldwide, prove the effectiveness of a wise and comprehensive climate risk management framework and shed light on its enormous potential to make people resilient to adverse climate events and, more generally, to climate change.

[93] R4 Rural Resilience Initiative – Quarterly report | January-March 2016, World Food Programme and Oxfam America

Conclusions

The purpose of this study was to investigate the social dimension of risk management, particularly by demonstrating its relationship with human resilience, the former as a "tool" that fosters the latter.

In order to contextualize the research carried out, a social setting was identified (the global South), together with a risk (climate risk) and a suitable management framework, namely the one to which the strategic partnership between Oxfam America and World Food Programme gave life in 2012: the R4 Rural Resilience Initiative.

The direct proportionality between poverty and weakness in front of adverse natural events represents only one dimension of the severe vulnerability suffered by poor communities worldwide, whose condition is often further aggravated by sluggish economies, fragile and rudimentary institutional settings, educational deficiencies, volatile commodity prices and harsh conflicts, a combination of factors that puts a strain on their food security.

Such a hard condition allows understanding the great potential that a reasoned and comprehensive climate risk management framework has to make these people resilient to climate change. The resulting higher stability is, in turn, source of a virtuous circle that firstly increases all the dimensions of their food security, and then gradually leads them out of the poverty trap. The underwriting of index insurance, the building of productive assets and the recovery of natural resources minimize the financial risk associated with natural disasters and the consequent stability boosts farmers' food security and confidence, resulting in the capacity to obtain credit at better rates. This encourages rural households to choose riskier but more remunerative solutions, invest in diversified activities and purchase fertilizers, seeds, technologies, animals and whatever capable of improving their productivity. Following droughts, they also avoid selling productive assets and reducing food and water intake, resulting in better health, better life quality, improved income, productivity, resilience or, in only three words, social and economic empowerment.

Among the four risk management components implemented by R4 partners, this paper focused on Weather Index Insurance, a risk transfer strategy. By documenting and analyzing its technical specifications, the study has generated insight into its greater adaptability to Developing Countries compared with traditional insurances, too stiff and expensive to meet the numerous constraints set in these areas. The paper closes by illustrating WII implementation in Senegal, second Country out of the four where R4 has been operating during the last few years.

In 2015, an impact evaluation commissioned on R4 Senegal revealed the success achieved thanks to this dedicated combination of forces. The study was run by Dalberg Global Advisors on a sample of 1,776 farmers in Tambacounda and Kolda and relied on qualitative and quantitative methodologies to analyze the extent to which R4 risk management strategies have supported farmers in building resilience against extreme climate events. Here are the key findings:

I – Despite two years of adverse climate conditions, R4 participants did not slide into food insecurity[94]*.* The declining of their livestock and agricultural production due to the exceptionally dry climate is undeniable, as it is the fall of their food consumption rate. This last is tracked by WFP's Food Consumption Score, a proxy indicator of the qualitative and quantitative dimensions of food security[95]. However, compared with farmers exposed to the same shocks, R4 participants managed to safeguard their food security, in fact their FCS only dropped by 8.1%, leaving them in what the FCS categorization identifies as "Acceptable food consumption" level. Differently, non-

[94] World Food Programme, Oxfam America, *Rural Resilience in Action. Preliminary results of the impact evaluation for the R4 Rural Resilience Initiative in Senegal (2013-2015).*

[95] FCS results from the weighted frequency (in terms of number of days per week) of intake of eight different food classes. Therefore, the tool categorizes households into Food Consumptions Groups (FCG). In Senegal, cut-off points are the following:
- Poor food consumption: 0-28
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participants' FCS plummeted by 49.1%, dragging them from an acceptable to a borderline food security level.

II – Rice harvests among R4 farmers increased ten times more than those of the control group[96], in particular 229.79 kg per household over the survey period compared to 20.13 kg. This result is mainly due to the risk reduction activities carried out by participants, such as the building of soil conservation mechanisms, irrigation and drainage systems.

III – Higher solidarity among rural households[97], largely explained by the risk reduction and saving activities held at community level: in-field discussions revealed how cooperation and participation have strengthened the social cohesion that, combined with organizational capacity, is essential when coping with natural disasters that hit the entire community.

A Chinese proverb says: "*When the wind of change blows, some people build walls, others build windmills*". Each longitude is exposed to specific risks and the R4 Rural Resilience Initiative is just one of the numerous frameworks being implemented worldwide: what brings them together is the honorable purpose of supporting human beings in growing stronger by encouraging their endurance and – who knows – the building of windmills.

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[96] World Food Programme, Oxfam America, *Rural Resilience in Action. Preliminary results of the impact evaluation for the R4 Rural Resilience Initiative in Senegal (2013-2015).*

[97] *Ibidem*.

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Summary

I had the precious opportunity to witness the joy in people from the global South when I managed to make their life a little bit easier, and this made me wonder: "what can be done to bridge the gaps in their ability to deal with the daily difficulties imposed by the economic, social and natural environment around them?" The energy that flows in those people cannot be blocked by the same things we cope with here with extreme simplicity; conversely, it has to be channeled to grow stronger and more resilient. "Risk Management" was the subject that, more than any other, would have provided me with strategic and analytical tools to address this study as thoroughly as possible and prove how a proper management of risk (before, during and after the adverse event) can be determinant in building resilience. In other words, I wanted to investigate the social dimension of risk management, particularly by demonstrating its relationship with human resilience, the former as a "tool" that fosters the latter.

With his "quantitative delirium" and the foolish exploitation of natural resources, Man is unceasingly challenging the environmental limits that define the finite nature of our system. This unsustainable administration of ecosystems and the consequent climate change have heavy impact especially on the poor, since they are more dependent on natural environment and on the goods it provides. The direct proportionality between poverty and weakness in front of adverse natural events represents only one dimension of the severe vulnerability suffered by poor communities worldwide, whose condition is often further aggravated by sluggish economies, fragile and rudimentary institutional settings, educational deficiencies, volatile commodity prices and harsh conflicts, a combination of factors that puts a strain on their food security. When losses inflicted by natural catastrophes meet the limited access to income-generating opportunities, the result is a compromised human welfare and a longer loss-recovery period. The evidence of such a disorder in crisis periods proves the need for climate risk management strategies.

Here comes the R4 Rural Resilience Initiative, a strategic partnership between the World Food Programme and Oxfam America, that is, the United Nations frontline agency in the fight against hunger and a global organization committed in addressing social injustices worldwide. Since 2012, the objective of such a strong combination of forces has been the improvement of food and income security of rural households. The initiative builds on the implementation of a sustainable natural disaster risk management framework that addresses in four complementary ways the issues encountered by the most climate-vulnerable people, with the aim of mitigating the financial and social impacts of natural calamities and thus alleviate the resulting food insecurity.

Following these considerations, I investigated the application of the enterprise risk identification framework in a context that well differs from the business reality. In particular, it has been applied to introduce the main risks faced by rural communities, thus shedding light on the sources of risk that threaten the agricultural sector and the livelihoods of those who depend on it. After analyzing the main issues arising during the qualitative risk assessment stage (especially when estimating likelihood and severity of worst-case scenarios), the prioritization of the perils identified leads to narrow them down to a list of key risks that are more likely to cause adverse impacts on production yields, incomes, and livelihoods, and on which the qualified Government should concentrate attention and resources. The paper focuses on weather-related risks, in particular on droughts, which The World Bank proved to be the major source of risk for agricultural production, due both to their frequency and severity in the last thirty years.

Among the four main risk management approaches (mitigation, transfer, coping and avoidance), the high-to-medium frequency and magnitude that characterize droughts drives to focus on risk transfer mechanisms. On this purpose, it is necessary to acknowledge the inappropriateness of traditional agricultural insurance in managing weather-related agricultural risk in developing Countries. That kind of insurance policy, in fact, would imply in-field assessment of damages, a procedure that both upsurges transaction costs (charged to insurance premiums) and delays payouts distribution, thus leaving farmers no chance but undertaking detrimental coping strategies in the period between disaster occurrence and indemnity payment. In addition, traditional insurances are designed to be applied to localized risks and complex conditions, a feature that impedes the application of the same contract on a group of people, which – on the contrary – would be another prerequisite to ensure low administrative and operational costs and, therefore, a low threshold of insurability.

The constraints set by Countries in the global South require the implementation of an *ad hoc* risk transfer mechanism, that is why R4 partners are implementing the so-called *Weather Index Insurance.* However, it is necessary to notice that its role is the augmentation of an already existing value proposition, an integrated risk management framework that is already functioning, as the one implemented within the R4 Rural Resilience Initiative. In case of lack or difficulty to access markets and financial institutions, Weather Index Insurance cannot express its full potential and unlock growth (especially credit) opportunities, which represent the starting point for the enhancement of people resilience against climate change. In particular, WII supports vulnerable rural households in coping with *current* weather-related risks and, if accurately designed and based on reliable technologies, perhaps also *future* risks triggered by climate change, thus preparing policyholder ahead of time and significantly contributing to the sustainable development of these communities.

Weather Index Insurance is a contract which performance depends on an objective parameter that measures a climate variable at a specific weather station during a defined time period. To make WII products' underlying index a trustable proxy for losses, it has to be centered on an objective parameter (millimeters of rain, temperature level, etc.) that presents high correlation with the variable of interest (crop yield). This parameter must meet prerequisites such as ease of observation, transparency, periodical detectability, observability over a wide area, properties that make WII work better when applied to *highly correlated and covariate* risks, meaning that the agricultural damage is a clear consequence of that climate risk (correlation) and that the insured parties are all affected by the same degree (covariance). When the index that tracks the weather parameter hits critic values that (may) correspond to an agricultural loss, all the insured policyholders who live in the area to which the weather station refers, receive payouts based on the same contract, thus field assessments are not required.

Once identified the climate risk to cover (rain, wind, etc.), the exposure assessment is performed to analyze crops' behavior in different stages of the plants growth in response to changes in weather conditions; plants, in fact, react differently depending on the phase of the crop cycle they are in, and some of these phases may be particularly critical to the crop quality or survival. This analysis is fundamental to design an index truly capable of catching the right crop needs and thus differentiate between rainfall timing, rather than limiting the detections to the rainfall accumulated over a unique and longer period. The crop model elaborated considering the plant's life cycle provides an essential input to the subdivision of the insurance period into different phases of measurement; on a general basis, we can distinguish three phonological phases: seeding/establishment, vegetative growth/flowering and yield formation/ripening. The detection of the index level is executed per each measurement phase that composes the insurance period, each one associated with a specific index threshold below which payouts are issued. The design of WII contract proceeds with the vulnerability assessment, namely the quantification of the potential financial impacts of an adverse weather event on farmers, for example on their income, investments, employment and debt. It might be useful to involve in the assessment process both experts and farmers: the former have the means to make a thorough analysis of the current risk management framework and can also run agricultural system monitoring; customers, on the other hand, deeply know their risk exposure, their soil and crops' criticalities and, more generally, their needs. The mutual sharing of this knowledge, which should also involve interviews, surveys and focus groups with all the stakeholders, is also known as *participatory stakeholder process* and is fundamental to draw clear vulnerability profiles of the districts involved.

During all these assessment phases, index designers model potential indices and submit them to customers' feedback, for example to review payout frequency, premiums amount, number of phases that should compose the covered period, etc.

Based on the qualitative and quantitative results of the previous assessments, the insurer sets the price of the insurance (amount of the premium). It reflects the probabilities of distributing payouts, which are in turn driven by the probability of hostile behavior of the indexed weather variable.

Many elements contribute to make it demanding the definition of a workable price: first of all the pressure to deliver a quality coverage at a low price, fair to both households and insurers, thus making index insurance affordable by the poorest. Secondly, establishing likelihoods implies a great deal of uncertainty due to the insufficient evidence generated by the rarity of some events and the lack of historical data, partially overcome by satellite figures and cooperation between farmers and experts. Lastly, price-setting follows the negotiations among insurers, buyers and reinsurers, each one with perceptions regarding future events that, despite the scientific assessments, may differ from those of the others due do the uncertainty variable that characterizes climate events. To define premiums, insurance companies resort to actuarial mathematics to determine the expected economic loss and a measure of how much their actual loss can deviate from the expected one. In case of natural events and almost all the other insurable events, their probability cannot be determined *a priori* (that is the case of a die roll or a coin flip, where the possibilities are limited and known) because their happening is influenced by countless factors and combinations, resulting in highly variable outcomes. In order to "extract" the probabilities associated with climate events, the loss frequency and the related magnitude, it is necessary to start by analyzing the historical datasets related to the weather variable in object (rainfall in this case) and its impact on crops. They are then summarized in a probability density function that shows the severity of possible events against their frequency and probability. This tool is useful to observe the expected economic loss (mean) and losses dispersion around the mean (standard deviation), which gives insights about how much the actual loss can deviate from the expected one. An example is provided to show how to apply these concepts to compute the pure premium that an insurance company should require to insure against groundnuts' exposure to drought risk in Senegal. The choice of this crop is not casual; peanuts' yield, in fact, is highly correlated to rainfall amount, a condition that ensures that in case of groundnuts' loss, it is highly probable that it is due to rainfall deficit.

Because of its nature, a constant constraint of index-based insurance products is the so called basis risk, which can be defined as the deviation of the farmer's individual yield loss from the district average or, similarly, the potential mismatch between the actual loss suffered by the insured parties and contract payouts (which are homogenous across the entire area covered by the insurance).

Basis risk can take several forms, for example a household experiencing loss but not receiving payout (or not enough), or payout being triggered without any loss suffered. On a general basis, it is possible to distinguish between three types of basis risk:

- *Product basis risk*: it occurs when there is no clear correlation between the indexed weather variable and crop losses, which may have been caused by other different factors. This is the reason why WII works better when adopted in areas with limited human intervention and to address severe meteorological events, which imply more widespread and consistent losses.
- *Spatial basis risk*: it refers to local variations in the hazard occurrence in the surroundings of the reference weather station. This risk increases as the geological homogeneity of the areas covered decreases.
- *Temporal basis risk*: it is generated when there is temporal misalignment between insurance period's phases and crop's growth stage.

These shadows of basis risk make it clear that the effectiveness of Weather Index Insurance depends on how well yield losses match with the contract's underlying weather index. Here are the following measures to reduce basis risk: use index-based insurance when there is evidence of clear correlation between agricultural damage and adverse climate event, select regions which morphology does not imply significant weather variability, target single-cropping areas to reduce the variability of plants' response to the same adverse event, define the insurance period's phases in line with the plants' life cycle, augment the density of weather stations in the target geographical area and engage debates among farmers, experts, agronomists and any other stakeholder to share relevant knowledge and make the index mirror reality.

To completely eradicate basis risk, separate contracts should be drafted on indices measured at the various locations where the contract is implemented, a procedure that would be expensive and would wipe out one of the most attractive features of index-based insurances (i.e. low transaction and operative costs).

Regarding its scope, WII is suitable for application at different social levels:

- *Micro* level (the one on which this paper focuses): small-scale farmers and households can insure their production based on temperatures and rainfall detected by local weather stations. These micro policies can be purchased as stand-alone products or within a package (e.g. credit, agricultural information, etc.), meaning that they can also be distributed to final holders by Financial Service Providers (FSPs), input suppliers, farmers' associations, Microfinance Institutions (MFIs) which have broader and more direct relationships with the target group than most insurers and also have vested interests in protecting their clients against adverse weather events. In fact, by making them purchase the insurance, these intermediaries benefit from the sounder financial stability of their customers: credit institutions can link WII to their lending operations and thus reduce default rates caused by weather shocks, while agribusiness firms may devise the link between WII and their products as a source of competitive advantage.
- *Meso* level: the same intermediaries mentioned above can also be policyholders. The insurance can be designed as a policy issued to (and purchased by) the organization (FSP, MFI, input supplier, etc.) but with payouts that can either directly or indirectly benefit the farmers that they have as customers in a certain geographic area. The Index Insurance, in fact, provides coverage to the aggregator that, in turn, hands down its benefits to farmers through a variety of services (e.g. credit packaging, contract farming or charging lower operating costs). In this way, the intermediaries protect their own exposure because they reduce the credit risk assumed by providing their typical services and alleviate mass loan defaults when weather shocks hit the area.
- *Macro* level: governments and relief agencies could benefit from an index insurance based on domestic weather observation, since they would receive early

liquidity following disasters and consequently they could lessen the risk of famine deriving from big losses in the stable crop. This would result in an enhanced national disaster management framework and in more rapid coping initiatives.

The paper closes with a case study, where firstly it is presented a short review of African Countries' exposition to droughts and floods, detrimental events especially for agriculture – the main economic activity on the Black Continent. The focus is then narrowed on Senegal, one of the four Countries where R4 partners are now concentrating their efforts and resources. Following the analysis of the irregular distribution that rainfall shows in Senegal, the case study proceeds by examining the relationship between Senegalese main rainfed crops and their exposure (or non-exposure) to wet conditions. Based on this background and on the development status of Senegalese insurance system, the chapter closes with a detailed description of Weather Index Insurance "landing" in Senegal, the contract design, features, implementation process, actors involved and the results achieved in the last two years in terms of improved food security and better quality of life.

Risk transfer mechanisms, and in particular Weather Index Insurance, are only one component of the wider risk management framework needed to build resilience to climate change and natural disasters. The R4 initiative counts on three other components, namely resource management through assets creation (*risk reduction*), microcredit and livelihoods diversification (*prudent risk taking*) and savings (*risk reserves*).

Studies and surveys conducted by the World Food Programme reveal that rural communities particularly value the *risk reduction* component since the tangibility of the assets built gives them real sense of the concreteness and effectiveness of the fight they are leading against climate risk. In Senegal, Ethiopia, Malawi and Zambia (the Countries where R4 is now present), thousands of meters of stone bunds are being created or reinforced to protect cultivated fields from sand and collect surface runoff; micro gardening activities (and related training sessions on how to manage a vegetable garden) are spreading throughout rural families to allow for a diversified diet while being self-sustainable; drainage systems to regulate and store runoff of rainfall water are being built to recharge groundwater when rain lacks. Reforestation, dams' reinforcement, distribution of seeds and farming tools, trainings on soil and water conservation and many other concrete actions are thickening the risk reduction component. Another tool that is proving to be successful in reducing climate risk is Food assistance For Assets (FFA) program, a cornerstone in WFP's resilience building plans since it addresses both the immediate needs of the most vulnerable (by distributing food, vouchers and cash transfers), and the urgency of resilience enhancement (by incentivizing the restoring of ecosystems, the rehabilitation of assets to reduce the impacts of climate shocks and so on).

On the *prudent risk taking* side, the "warrantage" practice is taking hold, a financial mechanism whereby farmers have the opportunity to store the surplus production in cereal banks allowing the latter to use the stock as a collateral for loans; this would prevent farmers from selling the extra products soon after the harvest, when the need for cash is high but prices could be low. Once reimbursed the loan, cereal stocks are released, hopefully in August, the peak of the lean season (no stocks left and crops still to be harvested). Thanks to this initiative, an increasing number of farmers are accessing credit in exchange for the stocking of tons of cereals. In addition, training is being delivered on microcredit principles, income generating activities and financial management (planning and budgeting) in order to raise awareness, provide farmers with the "instruments" to let them proactively participate to financial discussion and index design and to engage the rural community in diversified and remunerative activities. Weather Index Insurance plays an important role in supporting the financial component of the risk management framework since it facilitates access to credit at better rates, serving as a collateral. The loan obtained thanks to WII, warrantage or microcredit solutions can be used to invest in seeds, fertilizers or technologies capable of improving the agricultural productivity.

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A Chinese proverb says: "*When the wind of change blows, some people build walls, others build windmills*". Each longitude is exposed to specific risks and the R4 Rural Resilience Initiative is just one of the numerous frameworks being implemented worldwide: what brings them together is the honorable purpose of supporting human beings in growing stronger by encouraging their endurance and – who knows – the building of windmills.