FESA MICRO-INSURANCE

Crop insurance reaching every farmer in Africa

Final report

January 2014

EARS Earth Environment Monitoring – Delft
FESA Micro-Insurance: Crop insurance reaching every farmer in Africa
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Scientific Final Report
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FESA Micro-Insurance: Crop insurance reaching every farmer in Africa
CONTENTS

FOREWORD 7

1 INTRODUCTION 11
  1.1 Traditional crop insurance 12
  1.2 Index-based insurance 12
  1.3 Satellite indices 13
    1.3.1 Reflection indices 14
    1.3.2 Precipitation 14
    1.3.3 Evapotranspiration 15
  1.4 Report objective and scope 15
  1.5 Report structure 16

2 DERIVING CLIMATIC DATA FROM METEOSAT 17
  2.1 Rainfall monitoring 18
  2.2 Evapotranspiration monitoring
    2.2.1 Calibration 19
    2.2.2 Atmospheric transmission and correction 19
    2.2.3 Atmosphere temperature mapping 20
    2.2.4 Observation height air temperature 20
    2.2.5 Net radiation 20
    2.2.6 Sensible heat flux 21
    2.2.7 Actual evapotranspiration 21
    2.2.8 Relative evapotranspiration 22
    2.2.9 Dealing with cloud cover 23
  2.3 The relation with crop yield 24
    2.3.1 Water limitation to crop growth: the SDK relation 24

3 VALIDATION OF METEOSAT DERIVED DATA 27
  3.1 Validation approach 27
  3.2 Validation pitfall 28
  3.3 Validation results 28
  3.3.1 Water balance validation SW Burkina Faso 29
  3.3.2 Validation of RE relation to crop yield 31

4 COMPARING EVAPOTRANSPIRATION AND PRECIPITATION DATA 33
  4.1 Evapotranspiration and precipitation time series 34
  4.2 Climatic average of evapotranspiration and precipitation yearly course 37
  4.3 Distribution of dekad precipitation and evapotranspiration data 37

5 ELEMENTS OF DROUGHT INDEX INSURANCE DESIGN 41
  5.1 Growing season phasing 41
  5.2 Timing the growing season 43
  5.3 Start of growing season window 43
  5.4 Triggering the growing season start 44
  5.5 Calculating growing season payout 45
  5.6 Setting strike and exit
    5.6.1 Agronomic approach 47
    5.6.2 Standard deviation approach 47
    5.6.3 Percentile approach 47
6  COMPARING RE AND PRECIPITATION BASED INSURANCE DESIGN 49
6.1  RE and PREC based payout for a standard 3 phase structure 49
6.2  Variations in strike and phasing 52
6.3  Discussion 54

7  EXCESSIVE PRECIPITATION INSURANCE DESIGN 59
7.1  Burkina Faso trial 61

8  PILOT PROJECTS 63
8.1  Drought insurance for maize growers in Mali, Burkina Faso and Benin 65
8.1.1  Insurance scaling up 69
8.2  Drought and excess precipitation insurance for French bean growers in Kenya 70
8.2.1  Drought insurance 71
8.2.2  Excessive precipitation insurance 75
8.3  Drought insurance for cotton farmers in Tanzania 78
8.4  Drought insurance for maize and rice farmers in Rwanda 81
8.5  Drought insurance for contract farmers in Malawi and Mozambique 84
8.6  Drought insurance for cotton and sorghum farmers in Kenya 88
8.6.1  Drought insurance for cotton growers in Kerio Valley 88
8.6.2  Drought insurance for sorghum farmers in Meru County 90
8.7  Drought insurance for wheat and maize farmers in Kenya, a different design 94
8.8  Summary of results and current prospect 99

9  MARKET OUTLOOK 103
9.1  Supply side issues 105
9.2  Demand side issues 106
9.3  Market outlook 107

10  SUMMARY AND CONCLUSIONS 109

ACKNOWLEDGEMENTS 117

REFERENCES 119
FOREWORD

by Prof. Dr. Kees Stigter, founding president of the International Society for Agricultural Meteorology (www.agrometeorology.org)

Early 2014, I published with Dr. Emmanuel Ofori (Ghana) a triptych review with the title “What climate change means for farmers in Africa”. This appeared in the African Journal of Food, Agriculture, Nutrition and Development (AJFAND), that is successfully published from Nairobi since 2000 (so we were the opening papers in Nr. 1 of Vol. 14).

In the middle panel of our triptych, we state that climate change already seriously influences the livelihood of African farmers. (...) In this review in three parts, climate change is approached by dealing with the three sides from which the danger comes: (i) global warming, (ii) increasing climate variability, (iii) more and possibly more severe meteorological and climatic extreme events. (...) Vulnerable communities are urgently in need of assistance, aimed at building resilience, and at undertaking climate change adaptation efforts to survive and to maintain their livelihoods.

The left panel of the triptych review starts with a compelling review of the present situation of food security, referring to African examples to improve the situation. Then the influence is discussed that the El Niño Southern Oscillation (ENSO) has on increasing climate variability as a consequence of climate change. (...). As a direct consequence of the capricious behaviour of particularly rainfall in West Africa, the adaptation of its farmers has lagged behind enormously. This statement is valid for most farmers in Sub-Saharan Africa.

The occurrence of more and possibly more severe extreme meteorological / climatic events, as another likely consequence of climate change, is discussed in the right panel of the triptych review, reviewing the literature and dealing for Africa with recent droughts and famines. It appears that there is more than sufficient proof that the numbers of disasters have risen globally, and on average at an increasing rate, over the last half a century, with more evidence in the later decades. Whether extreme hazards have not only a shorter recurrence time but also have become more severe cannot be easily determined. This is due to developments in observations, populations and vulnerabilities and lack of developments in climate models. Only for increased temperature related disasters, severity has clearly become larger.

It is against the above background, in our three recent papers in AJFAND, that this FESA publication must be read. If and when the mentioned coping strategies fail, and they frequently do, immediate solutions are locally needed. They must save poor farmers from complete ruination so that calamities do not wreck their future chances of restoring their farming systems for production in better seasons and years. Community based individual insurance on a large scale can be a very good contribution to such solutions, but special care has to be taken that the schemes are also available to the more vulnerable low-income individuals.

The Wikipedia (2014) learns that micro-insurance is the protection of low-income people (those living on between approximately $1 and $4 per day) against specific perils. It does so in exchange for regular premium payment proportionate to the likelihood and cost of the risks involved. This definition is exactly the same as one might use for regular insurance except for the clearly prescribed target market: low-income people. The target population typically consists of persons ignored by
mainstream commercial and social insurance schemes, as well as persons who have not previously had access to appropriate insurance products.

The author of this definition adds that micro-insurance does not refer to: (i) the size of the risk-carrier (some are small and even informal, others very large companies); (ii) the scope of the risk (the risks themselves are by no means "micro" to the households that experience them); (iii) the delivery channel: it can be delivered through a variety of different channels, including small community-based schemes, credit unions or other types of microfinance institutions, but also by enormous multinational insurance companies, etc.

Insurances function on the concept of risk pooling, and likewise, regardless of its unit size and its activities at the level of single communities, so does micro-insurance. Micro-insurance links multiple small units into larger structures, creating networks that enhance both insurance functions (through broader risk pools) and support structures for improved governance (i.e. training, data banks, research facilities, access to reinsurance etc.). This mechanism is conceived as an autonomous enterprise, independent of permanent external financial lifelines, and its main objective is to pool both risks and resources of whole groups for the purpose of providing financial protection to all members against the financial consequences of mutually determined risks.

Definitions therefore all include the critical features of:
1. Transactions are low-cost (and reflect members’ willingness to pay);
2. Clients are essentially low-net-worth (but not necessarily uniformly poor);
3. The essential role of the network of micro-insurance units is to enhance risk management of the members of the entire pool of micro-insurance units over and above what each can do when operating as a stand-alone entity.

Micro-insurance is a low cost, high volume business. Unless costs are contained, agricultural micro-insurance cannot be sustainable. Making products compulsory is one of the few ways micro-insurance schemes can reach the high volumes they need to become sustainable. Advantages and disadvantages of this have to be outweighed carefully. When carefully prepared, drought micro-insurance can play a great role in climate adaptation strategies, combating impoverishment and obtaining a more sustainable development.

Micro-insurance makes it possible for people to take more risks. When farmers are insured against a bad harvest (e.g. resulting from drought), they are in a better position to grow crops which give high yields in good years, and bad yields in years of drought. Without the insurance, however, they will be inclined to do the opposite; since they have to safeguard a minimal level of income for themselves and their families, crops will be grown which are more drought resistant, but which have a much lower yield in good weather conditions (Wikipedia, 2014).

I have always believed that science can support many poverty alleviation attempts, when we take care that also the applied scientists understand contexts as given above. The story below confirms that also in developing countries relevant applied research can easily be done. When I worked as a resident professor at the University of Dar es Salaam, Tanzania, in the late seventies and early eighties of the previous century, trustable potential evaporation (at that time just renamed as reference crop evaporation) calculations were internationally an important issue for support of determining crop water requirements. In the strongest physics based equation in use, the radiation term is in the tropics often the most important one. Therefore, simple
trustable solar radiation quantification with a high spatial representativeness was crucial. In this context we were interested in differences between point cloudiness and areal cloudiness, which were due to the problem that cloudiness was commonly observed twice a day visually by observers from a meteorological station. This gave point cloudiness while satellites had just started to quantify areal cloudiness.

Now we found at the time that the complement of “sunshine duration”, measured with a Campbell Stokes instrument, could be called “shade duration”. This “shade duration” came much closer to the areal cloudiness observed by satellites and thus also “sunshine duration” was indeed rather representative for radiation received at the earth surface. We even found that twice a day data at observational hours in Tanzania, corrected for the problem of being point cloudiness, represented well the average areal cloudiness for the day. This made satellite data users very happy because satellites did measure areal cloudiness in one place twice a day. But in this way there was also a simple spatially representative proxy for solar radiation received at the earth surface, with a high spatial density.

The above story came back to me when reading the report before you. What is needed in drought micro-insurance is a best possible proxy (index) of agricultural drought. Rainfall is an extremely useful parameter to be measured by farmers on their plots, to relate it to the growth of their crops and to get “live recording” of ever higher local rainfall variability, this way increasing their understanding of soil moisture conditions. However, it is substantially less suitable for purposes of representing agricultural drought for reasons well dealt with in this report.

The index used here is that of satellite derived Relative Evapotranspiration (RE) that represents actual water use by the crops. And in addition a satellite derived Relative crop Yield (RY) index is used to represent the effect of lack of water, so drought, on yields, that is crop losses. For every crop there is proportionality between the yield deficit (1-RY) and the evapotranspiration deficit (1-RE). This proportionality is the very basis for using the satellite derived RE as a measure of agricultural drought and as an index for agricultural drought insurance. The risk of the latter, due to drought, is then related to the probability that RY falls below a trigger value related to insurance pay out. RY provides a crop specific measure of yield deficit due to drought.

From a theoretical point of view, RY has the lowest intrinsic basis risk (as a measure of minimum risk for the insurance provider), certainly when compared to the satellite based indices historically explored: NDVI (Normalized Difference Vegetation Index) and precipitation. RE and RY can also be produced very economically. Moreover, the approach can easily be scaled up. Larger scales, with a high number of insurance clients, will enable not only economies of scale, but also allow for better risk spreading and therefore lower re-insurance costs. A study by the Agricultural Economic Institute (LEI, Wageningen UR) concludes that the market outlook for satellite RE index based micro-insurance is positive and can be turned into a sustainable activity. It is clear, however, that the “demand side” issues of understanding and trust require due attention.

Besides evapotranspiration, the Energy and Water Balance Monitoring System is also generating rainfall data fields. The methodology is based on cloud presence at different levels. These rainfall data have so far not been used for drought insurance because of the unknown faith of the precipitation. Much of the rain may not reach the plant, but runs off or percolates to greater depth. Instead, this type of Meteosat derived data is used for excessive precipitation insurance. Excessive precipitation is the result of long duration rain storms from Cumulonimbus clouds. Therefore the
Cold Cloud Duration (CCD), being the dwelling time of Cumulonimbus clouds, is used as an indicator. This is all detailed in this report, but the lesson is that the satellite data, once well calibrated with historical data, do not necessitate further ground backing for insurance pay out. Such historical data do hardly exist for any meteorological parameters related to drought that are measured in the classical way. It was already difficult enough to find historical yield data that could be trusted.

A look into the details gives stories like in Chapter 6, where the authors studied some elements of micro-insurance contract design. Given the current state of the art, a multi-phase contract structure was implemented. However, such a multi-phase structure, with a relatively short flowering phase, becomes critically sensitive to an accurate start of the growing season. For this reason, the multi-phase insurance approach is extended with a method of timing the start of the growing season and determining the corresponding sowing window automatically from 30 years of satellite data. This shows the force of satellite data availability but also the necessity of validation exercises.

In Chapters 7 and 8 there is an extensive look at validation pilot projects of which some were run in real time and some were “dry runs”. Reading the impressive details one can only agree with the conclusion of that chapter that the outlook for further deployment of FESA Micro-insurance can be considered auspicious. In comparison with some recent historical results reviewed in Chapter 9, it should be realized that the RE data developed in the FESA project cover a history of 32 years, have 3 km spatial resolution and can be provided for any location in Africa. There is no other index coming close to this areal availability of historical data. It is shown that in terms of availability of measurements the RE index performs from almost 80 to over 300 times better than any of the rainfall based micro-insurance projects concerned.

The FESA RE index is not offered as pure data, but as a complete insurance index service, including design of the index and monitoring of the index during the growing season. Current pricing of this service is such that at large scale application, costs per insured go down to some 0.5 euro per farmer. This implies that near every rain gauge there would have to be at least 1000 farmers to be insured and (in view of the depreciation) for a period of at least 10 year, so as to bring the data gathering costs at a similar low level as in the case of the RE index. Satellite based indices are widely available, of the same quality and fully compatible. In particular, the Meteosat based FESA Micro-insurance approach can truly reach every farmer in Africa.

It remains important to continue to demonstrate the correlation of RE data with crop yield, although in Africa this is often hampered by bad or lacking crop yield statistics. Contrary to my relatively simple cloudiness/radiation example from Tanzania, the approach used here is much more complicated, the parameters/indices much more complex and assessments often indirect. But the validation exercises are much more promising than they can be for the other approaches. The RE index, with its high resolution, has the advantage of being more site specific than the rain gauge based products. Together with the fact that these indices can be produced at low costs, that is what gives me the necessary trust in the approach. The final task will be to bring that sense of trust also to the stakeholders involved, through serious attempts to inform them about the seasonal developments derived from this new approach.

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INTRODUCTION

Insurance is a long existing risk sharing mechanism, recognized as an essential requirement for socio-economic development. Insurance against drought and other adverse climatic events has raised considerable interest and is advocated as a tool to:

- Protect the population against adverse climatic events, so as to decrease poverty and foster economic development.
- Prepare for disasters and provide funding for immediate mitigation, as an alternative to emergency aid.
- Provide a mechanism to adapt to and cope with climatic change.


Traditional insurance is still too expensive to be affordable to the poor. Micro-insurance seeks innovative ways to reduce costs and to provide an affordable but reliable mechanism of risk sharing.

Crop insurance has an important social-economic spin-off. It prevents farmers from falling into the “poverty trap”, that occurs if after crop failure they have to sell their productive assets and lose their capability of gaining an income through farming. On the contrary, having insurance may allow them to obtain credit and to invest in the intensification of agricultural production by buying fertilizers, pesticides and high quality seed. In this way farmers can considerably increase their production and income. For this very reason micro-insurance is an essential tool in reaching Millennium Development Goal Nr. 1: the reduction of extreme poverty and hunger.

This document is the final report of FESA Micro-insurance project. This project was commissioned early 2009 by the Netherlands Minister of Development Cooperation as a contribution to reaching the UN Millennium Development Goals. The project aims to develop a satellite based agricultural insurance system that reaches every farmer in Africa. This report discusses and demonstrates the utility of Meteosat data for this purpose.

Focus is on the Meteosat derived relative evapotranspiration (RE), derived through the Energy and Water Balance Monitoring System (EWBMS). This system was developed by EARS since the early 1980’s (Rosema 1983, 1990, 1993). It can be considered a typical product of the “Dutch Remote Sensing School” that developed in the Netherlands Interdepartmental Working Community for Application of Remote Sensing (NIWARS: 1971-1977). From 1993 on, EARS is operating its own satellite data reception and processing facility. Main outputs of the EWBMS are temperature, radiation, evapotranspiration and precipitation data fields. These data cover the land surface of the entire hemisphere. The relative evapotranspiration (RE) is known to be directly related and proportional to crop growth. RE is therefore used as agricultural drought index.

Besides evapotranspiration, the EWBMS is also generating rainfall data fields. The methodology is based on cloud presence at different levels. These rainfall data have so far not been used for drought insurance because of the unknown faith of the precipitation. Much of the rain may not reach the plant, but runs off or percolates to greater depth. Instead, this type of Meteosat derived data is used for excessive precipitation insurance. Excessive precipitation is the result of long duration rain storms from Cumulonimbus clouds. Therefore the Cold Cloud Duration (CCD), being the dwelling time of Cumulonimbus clouds, is used as an indicator.
1.1 Traditional crop insurance

In developing countries the traditional type of crop insurance has widely failed (Pierro 2008). In a business sense traditional agricultural insurance is considered inherently non-sustainable and has always been subsidized (Roth et al. 2009). The causes for lack of success are:

- High correlated risk, causing high costs for re-insurance.
- Adverse selection: farmers with high-risk represent the majority of buyers.
- Moral hazard: farmers loose incentives to make a best effort.
- Fraud: evidence is manipulated to support a claim.
- Lack of transparency, particularly in relation to claim assessment.
- Late payout due to extensive claim verification.
- High costs, due to extensive monitoring, administration and claim verification.

1.2 Index-based insurance

In response to the aforementioned problems, index based crop insurance has been explored in recent years (Hazell et al. 2010, WFP/IFAD 2011, World Bank 2011, Gommes and Kayitakire 2013). With such insurance the farmer is not insured against crop loss, but against the adverse climatic conditions that cause crop loss. In relation to drought, the index could for example be the rainfall during the growing season. The positive elements of such index-based insurance could be:

- Low costs of monitoring and administration
- Low moral hazard, as the index does not depend on the farmer
- Less adverse selection
- Transparent: trigger and payout can easily be verified
- Fast pay out, since no damage assessment is needed
- Potential to be economically self-sustainable

However, index insurance also introduces some problems or demands, in particular:

- The index may be insufficiently representative for the loss to be covered, leading to inappropriate payouts, called “basis risk”.
- Need for long index data series, so as to be able to assess the risk and to develop and price the insurance.
- High data requirements, which may require high investments in measuring stations and high costs of their operation and maintenance.

In relation to drought, rainfall seems a logical index, particularly because it is close to people’s perception of drought. Rainfall is indeed the source of water for plant growth, but not all rainfall is used by plants. A part runs off, and a part percolates to greater depth outside the reach of the plant roots. Moreover the water provided to the root zone of the plants may be stored for a considerable time. Water use by plants depends on radiation. This introduces considerable uncertainties and may pose considerable problems in the formulation of the index.

The problem may be addressed by involving a soil water balance model, which is fed by the precipitation and simulates how much water remains available in the root zone to the plants. For such a model to work properly, knowledge of the soil infiltration coefficient, water holding capacity and water conductivity is required. Such information is usually not available or can only be estimated roughly on the basis of soil type and soil depth. An example of such approach is the Water Requirements...
Satisfaction Index (WRSI) developed at FAO by Gommes (1983) which provides an estimate of the water availability relative to the crop water needs. The WRSI has been used in a disaster insurance contract by AXA with the Ethiopian government and also in insurance contracts, which were a part of the Millennium Villages Project (Hellmuth et al. 2009).

More elaborate approaches go beyond the water availability and use coupled crop growth models to estimate the effects of water availability on crop yield. The Agriculture Insurance Company of India has used the INFOCROP model. By replacing the rainfall indicator with the WRSI or even an estimate of crop yield as index, the intrinsic basis risk may certainly be reduced, but an important shortcoming that remains is the spatial basis risk related to the sparse availability of reliable rainfall data.

Rainfall in Africa is very variable. To adequately represent the spatial variation of convective rainfall systems, the distance between rainfall stations should not be more than a few kilometres. Current drought insurance practice requires the insured to live within a distance of 25 km from a suitable rainfall station. This, however, is very questionable and will imply a high spatial basis risk, leading to cases of inappropriate payout. In fact the number of suitable rainfall stations in Africa is very low. This not only causes a high spatial basis risk, but also limits scaling up of the insurance. Scaling up is badly needed to make drought insurance self-sustainable. A possible solution could be to establish many new rainfall stations. Rainfall stations, however, are costly, not only from the investment point of view, but particularly in terms of operation and maintenance. Moreover installing more rainfall stations does not solve the need for long time series to assess and price the risk.

1.3 Satellite indices

Because of the problems related to ground measured indices, as discussed in the previous section, there is a growing interest in satellite data. Such data are continuous in space, could reduce spatial basis risk and offer potential for insurance scaling up. On the other hand, some of these approaches may introduce a higher intrinsic basis risk in the sense that the quantity measured from space shows insufficient bearing on the type of risk to be insured, i.e. the risk of crop failure due to drought.

Satellites may cover entire regions with sufficient spatial and temporal resolution to adequately represent the variability of weather and crop conditions. In relation to micro-insurance important questions are:

- Do satellite derived indices really represent drought and crop yield, in other words: do they not introduce high intrinsic basis risk, and
- Do these indices provide high performance at low-costs; are they cost-effective?

With respect to cost-effectiveness, geostationary meteorological satellites show high potential. They are characterized by:

- sufficient spatial resolution (3-5 km grid size)
- adequate temporal resolution (1 hourly repetition)
- reliable operational systems, backed by a large meteorological community
- regional to continental data coverage
- low data costs

On the basis of geostationary satellites several type of data products are currently known, which are discussed in the following sub-sections.
1.3.1 Reflection indices

Well known is the Normalized Difference Vegetation Index (NDVI), based on the earth surface reflection in the red (R) and near infrared (NIR) spectral band: \[ \text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}}. \] The reflection spectrum of bare soil or rock is quite flat. Plant leaves, however, have a low reflection in the red (due to absorption by chlorophyll) and a very high reflection in the near infrared (due to low absorption and strong scattering). Therefore the NDVI is low for soil and rock, and high for a plant canopy. The NDVI is essentially an indicator of canopy closure. The index is sometimes used as an indicator of the quality of the growing season and of crop yields to be expected. This is however questionable because the NDVI is only a measure of greenness and vegetation cover and not of biomass production.

There are also other indices that have been proposed as indicators of crop growth. An example is APAR and fAPAR. They are used in the supposition that “absorbed photosynthetic active radiation” is an indicator of crop growth. Although this indicator may represent light interception, it does not give information on the partitioning of absorbed solar energy between photosynthetic electron transport and heat, which is highly variable. In this sense these indices do not offer significantly more information than the NDVI.

1.3.2 Precipitation

The use of satellite data for rainfall monitoring has a long history that is well documented in Barrett and Martin (1981) and Kidder and Von der Haar (1995). Operational monitoring of rainfall over the African continent has been pioneered since the 1980’s by the TAMSAT group at the University of Reading, United Kingdom, and by EARS in Delft, the Netherlands (Rosema 1990). EARS was the first to map rainfall across the African continent and also implemented the technology for east and south-east Asia.

For rainfall monitoring two types of satellites may be used: the more general meteorological satellites providing imaging capability in the visible and thermal infrared and dedicated satellites providing microwave imaging instruments. Examples of the first are the METEOSAT, GOES and FY2 geostationary meteorological satellites. An example of the latter is the Tropical Rainfall Mapping Mission (TRMM). However, this satellite suffers from relatively low spatial resolution and low repeat coverage.

The methods used by the TAMSAT group and by EARS are based on the TIR band on board of geostationary meteorological satellites. On the basis of radiation temperature measurements, clouds are classified according to their height. This is typically done every hour and the presence of the different cloud height classes is counted during a certain period, usually a day or a 10-daily period (dekad). The resulting figures are called “cloud durations”. Subsequently a statistical relation between the cloud duration(s) and the rainfall is sought by means of mathematical regression analysis.

In the TAMSAT approach only very high or so-called “cold clouds” are used. The relation between rainfall and “cold cloud duration” (CCD) is calibrated against historical data from available rainfall stations. A disadvantage of this approach is that the calibration coefficients have appeared to be very variable in time and space and historical calibration coefficients may not be valid today. Another disadvantage is that
the use of only the CCD makes the methodology less suitable for advective and orographic rainfall and thus restricts continent wide application.

The method developed by EARS is based on multiple cloud height classes and corresponding cloud durations (CD’s), as well as on a rainstorm vigour indicator called the cloud top “temperature threshold excess” (TTE). Calibration is done in near real time by means of multiple regression against WMO-GTS rain gauge data. The limited availability of GTS rainfall stations in Africa, however, may also impose a limitation to this real time approach.

A disadvantage of rainfall as crop growth indicator is, that it is not known how much of the precipitation is available to the crop. A considerable part of the precipitation may run off, depending on soil infiltration characteristics and slope. Of the rain that infiltrates the soil, a considerable part may percolate to deeper layers outside the reach of plant roots. However, as discussed in section 1.4, an additional water balance and crop growth model could help to address this problem and “translate” precipitation in information more closely related to crop production deficit, although such a model would require additional information on soil type and depth.

1.3.3 Evapotranspiration

Besides developing satellite based rainfall mapping, EARS has been pioneering the derivation of actual evapotranspiration from Meteosat since the early 1980’s. In this way the company has become the only routine provider of both satellite rainfall and evapotranspiration data.

In principle evapotranspiration consists of two components. One is water loss through the plant leaves, also called transpiration, and the other one is water loss from bare soil. Bare soil evaporation, however, is on average very small. This is caused by the fast development of a dry surface layer, which isolates the soil from further water loss to the atmosphere. Transpiration from plants is by far the dominant component.

It is well documented in the plant physiological literature that evapotranspiration is proportional to CO₂ uptake and consequently to plant growth and crop yield (Stewart et al. 1973, 1977, Doorenbos and Kassam 1979, Slabbers et al. 1979). For this reason actual evapotranspiration is fundamentally a better indicator of crop growth than precipitation. An operational advantage of the satellite derived evapotranspiration data is that, contrary to satellite derived rainfall products, no additional ground data are required.

1.4 Report objective and scope

Meteosat provides abundant information that is suitable for the development of an index insurance system that overcomes the disadvantages of indices measured on the ground. These disadvantages are in particular:

- high intrinsic and spatial basis risk,
- high data collection costs
- difficulty to scale up the insurance system
In this publication we report the development and implementation of drought and excessive precipitation insurance based on Meteosat derived indices. These data have the following distinct advantages:

- They are close to the actual risk addressed, i.e. crop failure
- They are from a single source
- They do not depend on measured ground data
- They cover the entire continent at 3 km resolution

These are important operational advantages, which may lead to high cost efficacy and allow for relatively easy insurance scaling up.

The use of Meteosat derived products for crop index insurance has not earlier been explored. Moreover there are almost no operational providers of such data. This may have contributed to a lack of knowledge and awareness in this field. It has been the objective of the FESA Micro-insurance project to investigate this new opportunity and to develop, test and implement a drought micro-insurance approach that reaches every farmer in Africa.

1.5 Report structure

The present chapter provides the introduction to the subject. Crop insurance is badly needed, but too expensive for smallholder farmers. Index insurance, suffers from lack of ground data. Possible solutions based on satellite data are discussed. The Meteosat derived relative evapotranspiration (RE) and cold cloud duration (CCD) indices are chosen for developing large scale index insurance in Africa.

In the following chapter 2 we discuss how rainfall and evapotranspiration data are derived from Meteosat, and how this information is related to crop yield. Chapter 3 discusses the validation of the Meteosat derived climatic data products. Thereafter, in chapter 4, historic data series of ground measured rainfall and Meteosat derived relative evapotranspiration are studied and compared. It is shown that these data give similar, drought related information.

Chapter 5 discusses the elements of drought index insurance design, including growing season structure, timing and payout formulation. In chapter 6 these index design elements are applied to develop and compare index insurance schemes based on both rain gauge data and the satellite derived relative evapotranspiration for the same locations. Finally, chapter 7 discusses the design of excessive precipitation insurance on the basis of the cold cloud duration index (CCD).

Chapters 2-7 present the work done on the development of the satellite database and the index insurance during the initial phase of the FESA Micro-insurance project (2009-2010). During the following three years (2011-2013) these new satellite based insurance indices have been tested in a number of pilot projects. In chapter 8, seven pilot projects are presented and discussed. This chapter is completed with an overview of all insurance design and pilot project results.

Towards the end of the FESA project also a market analysis and outlook study for the Meteosat based index insurance services has been performed by the Agricultural Economic Institute (LEI Wageningen UR). A summary of this analysis is presented in chapter 9.

Finally chapter 10 present a final report summary and draws overall conclusions.
DERIVING CLIMATIC DATA FROM METEOSAT

Meteosat is in orbit since 1978. There are two generations: Meteosat First Generation (MFG) from 1978 to 2006, and Meteosat Second Generation (MSG) from 2004 to date. EARS has been processing Meteosat data since the early 1980’s and is operating a satellite receiving station since 1992. However, storage limitations in the early days and later technical modifications in the processing chain have caused an incomplete historical data set. With help of EUMETSAT in Darmstadt and the Royal Netherlands Meteorological Institute (KNMI), it has been possible to compose a fairly complete data base of the following hourly visual (VIS) and thermal infrared (TIR) data:

- MFG: May 1982 – April 2006 from EUMETSAT
- MSG: April 2004 – December 2005 from KNMI
- MSG: January 2006 – date EARS reception

In this way an archive of 32 year of hourly visual and thermal infrared Meteosat images has been created, suitable for processing to relative evapotranspiration (RE) data. The visual (VIS) and thermal infrared (TIR) bands on the MFG and MSG satellites are somewhat different. For example, in the visual there are 2 bands on MSG and only 1 on MFG. In the MSG case the 2 separate bands are combined into one, in such a way that we get the same information as in the single band on MFG. Both are then converted in the same way to albedo (reflectivity). For the period of overlap in MFG and MSG reception, i.e. between April 2004 and April 2006 we have done inter-calibration exercises. Another difference between MSG and MFG is the spatial resolution. MFG had 5 km, while MSG has 3 km spatial resolution. The climatic data products of each satellite are generated in the original projection and resolution. Only thereafter the products are reprojected and resampled to an equal latitude/longitude grid.

The climatic data products are generated on the basis of Meteosat hourly images by means of the *Energy and Water Balance Monitoring System* (EWBMS). A schematic overview of this system is presented in figure 2.1. There are two parallel processing lines, one to derive the rainfall and one to derive the components of the energy balance, in particular radiation and evapotranspiration. In addition there are sub-systems that use the previous data to generate dedicated products for specific applications, such as river flow forecasts, drought maps, and crop yield forecasts. In the following sections of this chapter the methodology that is used to derive these data is briefly described.

![Figure 2.1: Overview of the Energy and Water Balance Monitoring System.](image-url)
2.1 Rainfall Monitoring

A statistical technique has been developed which is based on the duration of cloud presence. Clouds are first identified and classified in height classes on the basis of their cloud top temperature, as measured every hour in the satellite thermal infrared images. See table 2.1.

The presence of clouds at the different cloud levels is then counted during a period of 1 or 10 days. This leads to cloud durations (CD), representing their dwelling time, expressed as a percentage. Also the temperature threshold excess (TTE) is determined, which is the difference in temperature between thunderstorm cloud tops and the underlying temperature threshold, and an indicator of rainstorm vigour.

To relate these quantitative rainfall indicators to rainfall measured in the ground, use is made of rain gauge data that are available in near real time from the World Meteorological Organisation (WMO) through their Global Telecommunications System (GTS). Local regression equations are derived between the satellite data and the WMO-GTS rain gauge data, i.e. one regression equation for each rain gauge station:

\[ R_{j,\text{est}} = a_{j,0} + \sum a_{j,n} \cdot \text{CD}_n + b_j \cdot \text{TTE} \]  

Here \( R_{j,\text{est}} \) is the rainfall estimate, \( \text{CD}_n \) is the cloud duration at cloud level \( n \) and \( \text{TTE} \) is the temperature threshold excess at the corresponding location. This regression equation is established for each rainfall station using the rainfall and the satellite derived cloud data at this station and the nearest 11 surrounding stations. The regression equation, however, is an imperfect estimator of rainfall. Therefore at each station the residual \( D_j \) between the estimated and the observed rainfall is also determined:

\[ D_j = R_{j,\text{obs}} - R_{j,\text{est}} \]  

Subsequently the coefficients \( a_{j,n} \), \( b_j \) and the residual \( D_j \) are interpolated between the GTS rainfall stations using a weighted inverse distance technique so as to obtain the corresponding values for each pixel \( i \). The rainfall field is finally calculated pixel by pixel using the interpolated coefficients and residual:

\[ R_i = a_{i,0} + \sum a_{i,n} \cdot \text{CD}_n + b_i \cdot \text{TTE} + D_i \]  

---

**Table 2.1: Definition of cloud levels and corresponding temperatures and heights.**

<table>
<thead>
<tr>
<th>CLOUD LEVEL</th>
<th>TEMPERATURE RANGE</th>
<th>HEIGHT RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>&lt; 226 Kelvin</td>
<td>&gt; 10.8 km</td>
</tr>
<tr>
<td>High</td>
<td>226 – 240 Kelvin</td>
<td>8.5 – 10.8 km</td>
</tr>
<tr>
<td>Medium high</td>
<td>240 – 260 Kelvin</td>
<td>5.2 – 8.5 km</td>
</tr>
<tr>
<td>Medium low</td>
<td>260 – 279 Kelvin</td>
<td>2.2 – 5.2 km</td>
</tr>
</tbody>
</table>
2.2 Evapotranspiration Monitoring

While rainfall monitoring is a statistical technique, based on cloud top temperatures, evapotranspiration monitoring is largely deterministic and based on the energy balance and the physics of energy and mass exchange at the earth surface. The calculation of actual evapotranspiration data is carried out in several steps: calibration, atmospheric correction, air temperature mapping, calculation of net radiation, calculation of sensible heat flux and determination of the actual evapotranspiration. The various steps are briefly discussed in the following sections.

2.2.1 Calibration

Calibration is the conversion of satellite digital numbers to meaningful physical values. As for the thermal infrared band, calibration coefficients are received from provider EUMETSAT. They allow conversion of the thermal infrared data into “planetary” temperatures. As for the visual band, the digital numbers are converted directly to surface albedo (reflectivity). A vicarious calibration method is used based on the known albedo of reference surfaces within the image, such as the ocean (2%), sand desert (42%), Cumulonimbus clouds (90%).

2.2.2 Atmospheric transmission and correction

The vicarious calibration procedure of the visual channel, as discussed in previous section, provides directly for a value of the surface albedo A. But the daily surface albedo images are contaminated by clouds, which tend to increase the measured albedo. A cloud free surface albedo map is composed taking the backward 30 day minimum albedo value of each pixel.

Transmission of global radiation through the atmosphere is based on a transfer model after Kondratyev (1969) that was extended to include, besides scattering, also absorption. The resulting atmospheric transmission ($t_a$) is a function of the atmospheric optical depth ($\tau$), the surface albedo (A), and the cosine of the solar zenith angle “$i_o$” and reads:

$$t_a = 1 / \{(k+\alpha)/\cos(i_o)- 2\alpha A \} \tau$$

(4)

Here $\alpha$ is the scattering coefficient (0.1) and k the absorption coefficient (0.03) of global radiation in the atmosphere. $\tau$ is taken at an average value of 1.86.

In the thermal infrared the effect of atmospheric transmission is described by the following empiric relation between the planetary temperature ($T_0'$), as observed by Meteosat, and the actual earth surface temperature ($T_a$):

$$(T_0'-T_a) = [k/\cos(i_o)](T_0'-T_a)$$

(5)

Here k is the correction coefficient and $i_o$ the observation zenith angle. The highest planetary temperature is extracted from the satellite thermal data. This value is assumed to correspond with the condition of no evapotranspiration. For this special case the actual surface temperature may be calculated from the daily net radiation. With this pair of planetary and actual surface temperature the correction coefficient (k) is determined. Subsequently all planetary temperatures are converted to surface temperatures.
2.2.3 **Atmosphere temperature mapping**

A novel technique has been developed to estimate and map the air temperature at the top of the boundary layer (\(T_a\)) from satellite data. The method is based on the relation between noon surface temperatures (\(T_{0,n}\)) and midnight surface temperatures (\(T_{0,m}\)), which may be written as:

\[
T_{0,n} = a \cdot T_{0,m} + b
\]  

(6)

The coefficients \(a\) and \(b\) in this relation depend on the solar zenith angle. They may be derived on the basis of regression between observed noon and midnight temperatures. A more stable approach is to derive them by means of a physical-mathematical model of the daily temperature cycle under solar radiation. Now, in addition we note that in the (theoretical) case of perfect heat transfer we would have:

\[
T_{0,n} = T_{0,m} = T_a
\]  

(7)

Consequently the air temperature at the top of the boundary layer then follows from:

\[
T_a = b/(1-a)
\]  

(8)

2.2.4 **Observation height air temperature**

The observation height air temperature is the air temperature at standard observation height, usually 2 meter (\(T_{2m}\)). This temperature is not needed for generating the actual evapotranspiration, since the latter depends on the difference between the surface and the boundary layer air temperature (\(T_a\)). Nevertheless the 2m temperature may be useful because it can be compared with measurements at meteorological stations. The 2m temperature results from turbulent mixing of air parcels rising from the surface and descending from the top of the boundary layer. So the 2m temperature can be considered a weighed mean of the surface temperature and the top of the boundary layer temperature:

\[
T_{2m} = a \cdot T_a + (1-a) \cdot T_0
\]  

(9)

In practice the relation is determined empirically by regression with observed temperatures and then reads:

\[
T_{2m} = a \cdot T_a + b \cdot T_0 + c
\]  

(10)

2.2.5 **Net Radiation**

Once the surface and air temperature data fields have been derived, the algorithm continues with the calculation of the (daily values of the) radiation components. There are both short-wave (solar) and long wave (thermal, terrestrial) radiation components involved. The net radiation (\(I_n\)) represents the radiation absorbed at the surface and converted into heat. It may be calculated as:

\[
I_n = (1-A) I_g - L_n
\]  

(11)
$I_g$ is the incoming direct and diffuse solar radiation, usually called “global radiation”. $A$ is the surface albedo or reflectivity. $L_n$ is the net long wave radiation loss. The incoming "global" radiation ($I_g$) may be calculated with:

$$I_g = f(c) \ t_a \ S \cos(i_a)$$  \hspace{1cm} (12)

Here $S$ is the “solar constant”, i.e. the solar radiation flux outside the atmosphere ($\sim 1367$ W/m$^2$), $t_a$ is the atmospheric transmission coefficient (eq. 4), $i_a$ is the solar zenith angle and $f(c)$ a function that corrects for cloudiness as hourly measured by the satellite during the daylight period. The solar zenith angle $i_a$ depends on longitude, latitude, time of the year and time of the day. The outcome of (12) is averaged for a day.

The net long wave radiation term ($L_n$) is the difference between the upward long wave radiation ($L_u$) and the downward long wave radiation ($L_d$). These fluxes, according to Stephan-Boltzmann’s law, depend on respectively the surface and the air temperature. Also emission coefficients have to be taken into account. The formulation of the net long wave radiation is:

$$L_n = L_u - L_d = \varepsilon_0 \sigma \ T_0^4 - \varepsilon_a \varepsilon_s \sigma \ T_a^4$$  \hspace{1cm} (13)

Here $T_0$ represents the daily average surface temperature. When a pixel is cloud covered at noon, the whole day is taken to be cloudy and a different procedure applies. The light transmission through the clouds ($t_c$) is first calculated from the cloud albedo and then the net radiation under the cloud is estimated with:

$$I_{nc} = (1-A) \ t_c \ I_g \quad \text{($L_n \approx 0$)}$$  \hspace{1cm} (14)

Under clouds the long wave radiation fluxes almost cancel and the net long wave radiation is taken to be negligible ($L_n \approx 0$).

### 2.2.6 Sensible Heat Flux

The sensible heat flux into the atmosphere is proportional to the average temperature difference across the atmospheric boundary layer ($T_0-T_a$). This temperature difference is directly derived from the satellite data. The simple formulation is:

$$H = C \ v_a (T_0-T_a)$$  \hspace{1cm} (15)

The daily average surface temperature $T_0$ is obtained as the average of the noon and midnight values. $C$ is the turbulent heat transfer coefficient, which depends on the aerodynamic roughness of the area and the height of vegetation. A theoretical model after Businger (1965) has been used to establish its value range. Moreover a correction is applied for decreasing air density with elevation above sea level.

### 2.2.7 Actual Evapotranspiration

Having determined the net radiation $I_n$ (section 2.2.5) and the sensible heat flux $H$ (section 2.2.6) the latent heat flux $LE$, i.e. the actual evapotranspiration in energy units, is obtained from the energy balance:
LE = I_n - H - P \quad (G \approx 0) \quad (16)

P is the radiation used for photosynthetic electron transport, approximately 10% of the daily solar radiation in case of full vegetation cover. The historic evapotranspiration course is used to mimic the development of the vegetation cover. The daily average of the soil heat flux (G) is very small and therefore neglected.

### 2.2.8 Relative evapotranspiration

The actual evapotranspiration, as measured through (16), depends on soil water availability to the plants, and on the net radiation. In practice it is useful to have a pure soil water availability measure to characterize agricultural drought. This is achieved as follows. First the potential evapotranspiration is calculated using a Priestly-Taylor approach, derived by simplifying the Penman equation:

\[ LE_p = c \cdot I_0 \quad (17) \]
Where \( c \approx 0.8 \). Next, the relative evapotranspiration (RE) is determined as:

\[
RE = \frac{LE}{LE_p}
\]  

(18)

The resulting relative evapotranspiration is fairly independent of the net radiation and, as we will see in the next chapter, a good measure of plant growth reduction due to water limitation or drought.

As shown in figure 2.3, the relative evapotranspiration is also quite well related to measured plant available water, which is the traditional indicator of agricultural drought. It is however not the same. From the theoretical point of view RE is a better measure of agricultural drought as it is directly related to crop growth. Uptake of water by plant roots is governed by the soil water tension, rather than the soil water content. The relation between the last two depends also on soil type.

![Figure 2.3: Empirical relation between satellite derived 2-monthly RE and plant available soil moisture content in the top 5 cm (left) and top 1 m of soil (right). (Soil moisture data: courtesy University of Salamaca, Spain).](image)

### 2.2.9 Dealing with cloud cover

In case of cloud cover the transmission of radiation through the clouds \( (t_c) \) is determined from the cloud albedo. The net radiation at the surface under clouds is calculated with (14). The actual evapotranspiration then follows from the assumption that the partitioning of energy between sensible and latent heat, and consequently the relative evapotranspiration remains constant. This comes down to assuming the relative evapotranspiration (RE) to be the same as during the last cloud free day:

\[
RE_{i+1} = RE_i
\]  

(19)

However, during the 2012 pilot in Burkina Faso, a dry anomaly in the relative evapotranspiration data product was noted at the start of the rainy season. This anomaly appeared to be caused by the persistent presence of clouds that, for a considerable number of days, made it impossible to obtain a measured update of RE according to equations (16) to (18). The algorithm was improved. Since in the tropics rain falls predominantly from Cumulonimbus clouds, the daily cold cloud duration (CCD) was used to simulate the increase of soil water availability under clouds:

\[
RE_{i+1} = RE_i + 2 \times CCD \quad (RE \leq 1)
\]  

(20)
The CCD is expressed as a fraction of time. So a 12 hour rain storm (CCD=0.5) would bring a fully dry soil (RE=0) back to potential evapotranspiration. After this improvement, the entire 30 year Meteosat database was re-processed and the observed problem appeared to be solved. Hereafter the Meteosat derived data and the pilot project results showed better agreement and coherence with the available ground measurements and information than before.

2.3 The relation with crop yield

Monteith (1977) demonstrated that the dry matter production has an almost unique relation with the total radiation intercepted by the foliage, independent of crop type. 1 Joule is roughly equivalent to 14E-10 kg dry matter. This equivalency implies that the daily dry matter production may be expressed in terms of the daily average global radiation ($I_g$) with:

$$\Delta B = a.C.I_g$$  \hspace{1cm} (21)

where $\Delta B$ : biomass production [kg/m².day]  
$C$ : fraction of soil covered by the vegetation biomass  
$I_g$ : daily global radiation [J/m²s]  
$a$ : conversion constant ($\approx 1.2E^{-4}$)

Monteith’s results were obtained for crops in England, so in a relatively small geographical area and most likely in the absence of drought stress. It is known, however, that with the increase of light level, the efficiency of light use for photosynthesis decreases. It is also known that water shortage will lead to stomatal closure and by consequence limitation of photosynthesis. Therefore we have to include these additional elements, leading to:

$$\Delta B = b.C.RY.\phi.I_g$$  \hspace{1cm} (22)

Where $\phi$ : light use efficiency  
$RY$ : relative growth/yield due to water limitation  
$B$ : conversion constant ($\approx 6E^{-4}$)

In relation to drought insurance particularly the effect of $RY$ on biomass production and yield is relevant. For this reason we will not discuss the light use efficiency here, but only the effect of water limitation, which is the most variable factor in the biomass production.

2.3.1 Water limitation to crop growth: the SDK relation

$CO_2$ uptake and consequently dry matter production is regulated by (partial) closure of the plant stomata in case of limited water availability. Since water vapour and $CO_2$ largely share the same diffusion path through the plant stomata, there is strong relation between evapotranspiration and $CO_2$ assimilation (Slabbers et al. 1979). A practical approach has been developed by Stewart (1977) and was verified on the basis of experimental data from all over the world by Doorenbos and Kassam (1979). This approach we refer to as the “SDK relation”:

$$(1-\text{RY}) = k \ (1-\text{RE})$$  \hspace{1cm} (23)
where  

\[ \text{RY} \quad : \text{relative yield } (= \frac{Y}{Y_p}) \]

\[ \text{RE} \quad : \text{relative evapotranspiration } (= \frac{LE}{LE_p}) \]

\[ k \quad : \text{yield response factor} \]

The yield response factor is crop specific and indicates the drought sensitivity of a crop. For example, the value for maize is 1.25, for winter wheat 1.0 and for sorghum 0.9. Values higher than one would indicate a drought sensitive and values lower than one a drought resistant crop. The SDK relation shows that for every crop there is proportionality between the yield deficit (1-\(\text{RY}\)) and the evapotranspiration deficit (1-\(\text{RE}\)). This proportionality is the very basis for using the satellite derived relative evapotranspiration as a measure of agricultural drought and as an index for agricultural drought insurance.
3 VALIDATION OF METEOSAT DERIVED DATA

In the previous chapter we have presented the FESA methodology to derive climatic data products from Meteosat and we have discussed the relation with crop yield. It was shown that Meteosat derived relative evapotranspiration (RE) is proportional to the relative yield. Therefore RE has a high potential to be used for drought micro-insurance. The product is closer and much more directly related to crop growth than precipitation. Rainfall based agricultural drought assessment methods, like the Water Requirement Satisfaction Index (WRSI), are in fact ways of estimating the actual evapotranspiration from the rainfall data.

Meteosat derived relative evapotranspiration and its use as an agricultural drought index is quite new. Relative evapotranspiration data were never routinely available before and EARS is still the sole operational provider of such data. But the key role of evapotranspiration in relation to crop growth is well understood for some 40 years, thanks to the work of Stewart (1973), Slabbers et al. (1979), Doorenbos and Kassam (1979) and others. Since the satellite based approach to evapotranspiration is relatively unknown, we pay attention in this report to the validation of these new data products.

3.1 Validation approach

Since the start of EWBMS system development, already in the early 1980’s, EARS has carried out a range of validation activities in the framework of its projects. This culminated in a very detailed validation of the system in the Yellow River basin during the period 2005-2009, where 4 dedicated flux-measuring systems were installed for this purpose. The EWBMS system implemented at the Yellow River Conservancy Commission in Zhengzhou, measures the water balance of the upper Yellow River basin (120,000 km²) within 1%.

Validation is usually carried out at different levels of the EWBMS system products. Opportunities for validation of the EWBMS system performance that all have been exploited are:
1. Validation of temperature products by comparison with temperature measurements at meteorological stations.
2. Validation of precipitation by comparison with rain gauge measurements.
3. Validation of radiation by comparison with radiometer measurements.
4. Validation of sensible heat flux by comparison with Large Aperture Scintillometer (LAS) measurements.
5. Validation of actual evapotranspiration with the difference between net radiation and sensible heat flux (see previous two).
6. Validation of the water balance, i.e. the difference between precipitation and evapotranspiration by comparison with catchment run-off.
7. Validation of crop yields by comparison of satellite derived RE data or yield estimates with reported yields.
8. Validation through human perception: people with relevant field information conclude that the satellite data products are consistent.
9. Cross validation, i.e. comparison with other, independently derived satellite data products.
3.2 Validation pitfall

When validating satellite data, we have to consider the following pitfall. In remote sensing one often speaks of “groundtruth” when ground data are considered that serve as a reference for the satellite derived data. However, “groundtruth” does not exist. All ground measurements or ground observations have smaller or larger errors.

If we compare satellite derived air temperature with air temperatures measured at meteorological stations, then we compare an average of an area of 10-25 square kilometre with a point measurement made at a meteorological station in that area. These two measurements do not necessarily have the same value. Therefore when we compare many such pairs of measurements and plot them in a XY-diagram, these points will never fit to a straight line and there will always be scatter. The quality of the relation between the satellite derived and ground measured data is expressed in terms of the correlation coefficient (R) and the standard deviation or root means square difference (RMSD). It should be noted that these are just measures of likeness between the two data sets. They do not tell which data set is most accurate.

If we compare satellite and ground measured temperatures for stations in Africa and Europe, we usually find higher correlations and smaller RMSD’s in Europe than in Africa, while the satellite measuring instrument is the same. This outcome does not tell us that the satellite is performing worse over Africa than over Europe, but indicates that the quality of the ground measurements in Africa is less than in Europe. This all should be kept in mind when carrying out validation work. The example given was for the air temperature, but similar considerations apply to other ground data, such as rainfall and reported yields.

Rain gauge measurements are just small samples from an extended and variable rainfall field. Thus sampling errors are involved. The representativity of individual rain gauges for larger areas is small and certainly restricted to the spatial scale of a rainfall event. Particularly in relation to convective rainfall in Africa this may be only a few kilometres. But also within such distances there may be considerable point to point variation in precipitation.

In relation to crop yields there are similar problems indicating that care should be taken when drawing conclusions from the comparison of satellite and ground data sets. The quality of the official yield assessments in Africa is variable. Elaborate assessments are often hampered by lack of qualified people, road infrastructure and funding. A problem, often encountered in Africa, is that crop yield is derived by division of crop production and crop area. Often, however, only harvested area is available and not planted area. In this way crop yields are overestimated, as failing crops may not be harvested. By consequence the area accounted for is too small. Therefore when comparing satellite derived yields with reported yields one always finds considerable scatter, and also here the fit between the data sets is usually better in Europe than in Africa. Brunner et al (1995) find reported yields in West Africa to have errors up to 30%.

3.3 Validation results

In the preliminary report that presented the results of the development phase of the FESA Micro-Insurance project (Rosema et al. 2010) we have presented a considerable number of validation examples, demonstrating the validity of the EWBMS climatic data derived from Meteosat. In the present, final report of the
project, we will present two significant additional results in the following subsections. These results are relevant in relation to the following key questions:

1. Are the evapotranspiration data as derived from the energy balance (equation 16) quantitatively reliable?
2. Are the relative evapotranspiration data indeed proportional to crop yield as suggested by equation (23)?

But also in the remaining part of the report the reader will find additional evidence that the evapotranspiration data and the RE agricultural drought index are fully consistent with available ground information.

### 3.3.1 Water balance validation SW Burkina Faso

The water balance of the earth surface requires the following condition to be satisfied:

\[
\text{Precipitation} - \text{Evapotranspiration} = \text{Run-off}
\]

We have both, precipitation and evapotranspiration data derived from Meteosat. They are derived in a completely different and independent way. The mapping of precipitation follows a statistical approach based on cloud durations. The relation is calibrated by means of available simultaneous WMO-GTS rainfall measurements (section 2.1). The evapotranspiration data are derived through an energy balance approach using Meteosat derived albedo and temperature as input in the calculations (section 2.2).

According to a study by Mahé et al (2008) run-off in West Burkina catchments is between 2 and 8%. This finding provides an opportunity to test the consistency of both the precipitation and evapotranspiration data generated with the EWBMS system. To this end we have arbitrarily chosen 4*11 locations in the agricultural areas near the towns of Dande, Solenzo, Tougan and Dedougou in west Burkina Faso. For these locations we have extracted the Meteosat derived precipitation and evapotranspiration time series 2005-2013. They are presented in figure 3.1. The rainfall data are much more erratic then the evapotranspiration data. The evapotranspiration continues for some time after the rainfall has stopped. These observations illustrate the buffering effect of the soils.

In figure 3.2 the cumulative precipitation and evapotranspiration are plotted. We have drawn trend lines through these wavy curves. From their direction coefficients we may assess the following average values

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>880.7 mm/year</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>840.7 mm/year</td>
</tr>
<tr>
<td>Run-off (mm)</td>
<td>40.0 mm/year</td>
</tr>
<tr>
<td>Run-off (%)</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

This result is right in the middle of the range of 2-8% provided by Mahé et al (2008) and presents convincing evidence of the reliability of the Meteosat derived evapotranspiration and precipitation data.
Figure 3.1: Meteosat derived precipitation (PREC) and evapotranspiration (ET) average time series for 44 arbitrary locations in west Burkina Faso.

Figure 3.2: Cumulative precipitation (PREC) and evapotranspiration (ET) average time series for 44 arbitrary locations in west Burkina Faso. Trend lines are added.
3.3.2 Validation of RE relation to crop yield

In the framework of our cooperation with the Agrhymet Regional Centre in Niamey, Niger, we have been studying the relation between the relative evapotranspiration and yield data in West Africa. Ideally we would like to have yield data at the best possible level of detail. Through the FAOstat and Countrystat websites, only national and at best provincial yield data may be obtained. As for Niger we have been able to get access to district level yield data from the Niger Ministry of Agriculture. This enables a comparison of district yields with district average relative evapotranspiration.

We have first averaged the Meteosat derived RE data fields for the growing season, July-September. The average growing season RE was then averaged by district. This was repeated for the years 2007 to 2011 for which sorghum yield information was available. For every year the growing season yields are subsequently plotted against the growing season RE. The result is shown in figure 3.3.

There is a fairly good relation between the sorghum district yields and the growing season RE values with a correlation of 74%. The standard deviation is 221 mm or 27% of the maximum reported yields (800 kg/ha). The dashed lines in figure 3.3 represent the 30% error margins in reported yields according to Brunner et al. (1995). 86% of all values are within these margins. Apparently a large part of the scatter may be explained by errors in the reported yields. On the other hand, RE is not the only yield explaining variable. There are many other factors, such as seed quality, fertilization, and pests that may influence crop yields. Therefore a lot of scatter in the graph below is always to be expected. Nevertheless this result confirms the overall strong relation between relative evapotranspiration (RE) and crop yield.

![Figure 3.3: Niger district sorghum yield versus growing season relative evapotranspiration (RE), showing a linear relation. Dotted lines represent the 30% error margins in reported yields according to Brunner et al. (1995).](image-url)
4 COMPARING EVAPOTRANSPIRATION AND PRECIPITATION DATA

There is similarity between the precipitation and evapotranspiration based approach to agricultural drought insurance. Both are based on direct or indirect estimates of crop water use. Though these approaches are similar, the data used is very different: ground measured rainfall versus satellite derived relative evapotranspiration. In the following sub-sections we study and compare the two types of data. The rainfall data are WMO standard rain gauge data from meteorological stations in Tanzania, made available through MicroEnsure. The satellite derived relative evapotranspiration data have been extracted from the FESA database as 10-day (dekad) RE averages at the same locations and for the same period 1984-2007.

Figure 4.1 provides a view of the location of the rainfall stations, superimposed on a Meteosat dekad actual evapotranspiration image. What strikes is the abundance of evapotranspiration data points compared to the limited number of rain gauge stations. When looking at the spatial variation in these data, the question rises whether a single rain gauge can reliably represent an area as wide as 25 km or 8*8 pixels.

Figure 4.1: Location of 21 meteorological stations in Tanzania superimposed on a dekad relative evapotranspiration map with values varying between 0 (black) and 100% (blue).
4.1 Evapotranspiration and precipitation time series

From the database we have extracted 10-daily evapotranspiration data series at the location of the twenty-one rain gauge stations in Tanzania for the period 1984–2007. The average precipitation and the average relative evapotranspiration time series is compared in figure 4.4. The data show a clear yearly cycle with an overall division in a “wet” and a “dry” season. Sometimes also a split in the wet season may be observed. Evapotranspiration is somewhat phase-shifted relative to precipitation: high precipitation precedes high evapotranspiration. This is logical: when the rains start the soil is depleted and evapotranspiration is low. During the period of rainfall the soils are replenished but evapotranspiration first remains low because there are many clouds and radiation is not providing sufficient energy. Only after the rainfall, when cloudiness is decreasing again, there is more and more solar radiation to evaporate water. Thereafter, during the dry season, evaporation is gradually decreasing as a result of soil water depletion.

To get a more overall impression of the quality of the yearly growing seasons, it is useful to determine a 130 day forward floating average of the precipitation and evapotranspiration data. This period is representative for the growing season length of maize. The result is shown in figure 4.5. The maximum values in the 130 day average RE and PREC graphs are well defined. These maxima represent the optimum 130 day growing season. The height of these maxima indicates the quality/productivity of the growing season, their location in time represents the start of the growing season.

We may also compare the RE and PREC values in an X-Y graph so as to get an impression to what extent the two sources provide similar information. Figures 4.2 and 4.3 show the result. There appears to be a fair linear relationship ($R^2=0.62$) for the dekad RE and PREC values. This relation becomes excellent when considering the 130 day average values ($R^2=0.89$) showing that the Meteosat based relative evapotranspiration, i.e. drought information is consistent with the ground measured rainfall.

![Figure 4.2](image1.png)  
*Figure 4.2: Scatter plot of dekad Meteosat derived relative evapotranspiration (RE) versus ground measured precipitation.*  

![Figure 4.3](image2.png)  
*Figure 4.3: Scatter plot of 13 dekad Meteosat derived RE versus ground measured precipitation.*
Figure 4.4: 10-Daily ground measured rainfall (blue) and Meteosat derived relative evapotranspiration (red) for the period 1984-2008. The data are the averaged records of twenty-one meteorological station locations in Tanzania. The data show a phase shift of the relative evapotranspiration relative to the rainfall.
Figure 4.5: 130 day forward average of ground measured rainfall (blue) and Meteosat derived relative evapotranspiration (red) for the period 1984-2008. The graphs pertain to the averaged records of twenty-one meteorological station locations in Tanzania. The height of each maximum indicates the quality/productivity of the growing season. The time of each maximum indicates the start of the growing season.
Crop growth depends on radiation and CO2 uptake, which is only possible if the plant has open stomata and is evaporating fully. The relative evapotranspiration is proportional to crop growth (section 2.3.1). Therefore, when considering figure 4.4 and 4.5, it should be realized that crop production is proportional and in phase with relative evapotranspiration (red graph), but may have a phase shift relative to rainfall (blue graph). Besides this phase shift, there are other circumstances which disturb the relation between rainfall and crop growth. In hilly or mountainous areas rain may run down the slope. In plains there may be considerable run-on from such slopes, both at the surface and in the sub-surface. In addition shallow groundwater tables may disturb the relation between precipitation and crop production. Relative evapotranspiration, however, has a direct, simultaneous and proportional relation to crop growth. This means that considerable improvement in accuracy may be possible, when basing drought insurance on relative evapotranspiration data.

4.2 Climatic average of evapotranspiration and precipitation yearly course

We may characterize the climate in terms of water availability at each location by averaging the historic PREC and RE data for each dekad. The results are shown in figures 4.6 and 4.7. Figure 4.6 clearly shows the two rainfall seasons in Tanzania: the short rains season during October-January (dekad 27-03) followed by the long rains season during March-May (dekad 9-15). After the long rains there is a dry period of 4 months (mid June-mid October).

A related periodicity is observed in the relative evapotranspiration data. At the beginning of the short rains (dekad 31-33) the relative evapotranspiration increases considerably. 7 locations reach an RE level as high as 90%, another 7 reach a level of 70-80%, both sufficient, though to a different level, for germination and growth. 5 stations remain low. Here crop growth is only possible after the start of the long rains in March. After the end of the long rains in May, there is a progressive decrease in relative evapotranspiration, and consequently in soil moisture and plant growth, until the start of the short rains in October.

4.3 Distribution of dekad precipitation and evapotranspiration data

Figure 4.8 and 4.9 present the distributions of the dekad precipitation and relative evapotranspiration data, as measured at the meteorological stations and as derived from Meteosat, respectively. The difference between the two distributions is quite remarkable. While the rainfall distribution is very skew, the evapotranspiration distribution is almost normal, except for the highest class RE=90-100%. This effect is due to the effect of precipitation, which raises evapotranspiration up to potential. The graphs illustrate that the more erratic rainfall inputs are buffered by the soil and later used by the plants in a much more gradual way. The overall data set may be characterized by the distribution parameters that are presented in table 4.1. The coefficient of variation (CV=Std/Avg) is much smaller for the relative evapotranspiration (CV=0.34) than for the precipitation (CV=1.48).
FESA Micro-Insurance: Crop insurance reaching every farmer in Africa

![Graph](image)

Figure 4.6: Climatic average yearly course of the ground measured precipitation at twenty-one locations in Tanzania.

![Graph](image)

Figure 4.7: Climatic average yearly course of the satellite derived relative evapotranspiration at twenty-one locations in Tanzania.

Table 4.1: Distribution parameters of dekad rainfall and evapotranspiration at twenty-one locations in Tanzania.

<table>
<thead>
<tr>
<th></th>
<th>Station average</th>
<th>stand deviation</th>
<th>skewness</th>
<th>kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>avg.</td>
<td>range</td>
<td>avg.</td>
</tr>
<tr>
<td>Precipitation</td>
<td>14...58</td>
<td>27</td>
<td>25...76</td>
<td>40</td>
</tr>
<tr>
<td>Evapotransp.</td>
<td>45...86</td>
<td>65</td>
<td>12...26</td>
<td>22</td>
</tr>
</tbody>
</table>
An interesting related question is how well index strike levels could be estimated from the rainfall or relative evapotranspiration climatic average. To this end we have plotted in figure 4.10 and 4.11 the 16 percentile of the precipitation and relative evapotranspiration historic data as a function of their average value. From these graphs it is clear that relative evapotranspiration percentile levels can be quite well derived from their average, while the opposite is true for the rainfall data. This underlines the erratic nature of the rainfall data. It suggests that there is considerable more intrinsic uncertainty in setting rainfall strike levels. This may cause inappropriate payout when using rainfall based index insurance. This problem is even magnified when the rainfall data are not measured at the location of the insured.

Figure 4.8: 1984-2007 distribution of dekad precipitation data for 21 stations in Tanzania.

Figure 4.9: 1984-2007 distribution of dekad relative evapotranspiration at 21 station locations in Tanzania.

Figure 4.10: Precipitation: 16 percentile in relation to average for 21 stations in Tanzania (1984-2007).

Figure 4.11: Relative evapotranspiration: 16 percentile in relation to average for 21 station locations in Tanzania.
5 ELEMENTS OF DROUGHT INDEX INSURANCE DESIGN

In the previous chapter it has been shown that the satellite derived relative evapotranspiration historic data series provide information that is compatible to and consistent with equivalent precipitation data series. The relative evapotranspiration data, however, are more closely related to crop growth than precipitation. In the present chapter we will discuss how these data series may be used for drought index insurance design. Section 5.1 addresses the issue of growing season phasing. The historic data series show that the precise location of the growing season varies from year to year. Therefore in section 5.2 and 5.3 the automatic determination of the growing season starting window and timing of the actual start is developed. Section 5.4 presents the set-up of a 30 year payout simulation or “burn analysis” and discusses the evapotranspiration and precipitation based payouts in dependence of index settings and growing season structure.

5.1 Growing season phasing

The current state of the art is well represented by the multi-phase contract structure proposed by Osgood et al. (2007) as described in the report: “Designing Weather Insurance Contracts for Farmers in Malawi, Tanzania and Kenya”, prepared for the Commodity Risk Management Group of the World Bank by the International Research Institute for Climate and Society (IRI) at Columbia University.

The design process followed by IRI is also guided by the “SDK relation” (23). In the IRI approach, the relative evapotranspiration is called the Water Requirement Satisfaction Index (WRSI) and is estimated from precipitation data using a soil water budget model. The soil is viewed as a bucket that is filled by rainfall and depleted by evapotranspiration. The actual evapotranspiration is assumed to be proportional with the degree of filling of the bucket. For proper WRSI calculations it is necessary to have additional information on surface run-off and infiltration, soil type, soil depth, and deep percolation.

Crops have different growth phases with different sensitivity to drought. In the earlier mentioned FAO document “Yield Response to Water” (Doorenbos and Kassam 1979), five growth phases are discerned: Establishment, Vegetative, Flowering, Yield formation and Ripening. Figure 5.1 provides an impression of these growth phases for a maize crop. The FAO report also documents the different drought response factors (k in equation 23) pertaining to each phase for a range of crops. Examples for groundnut, maize and sorghum are presented in table 5.1 below. It is noted from these figures that the crop is most sensitive to drought (high k-value) during the flowering period, followed by the grain filling period. During establishment, vegetative and ripening the sensitivity is fairly low.

Table 5.1: Growth phases, their length and yield response factors to drought (k).

<table>
<thead>
<tr>
<th>Growth Phase</th>
<th>Groundnut</th>
<th>Maize</th>
<th>Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>days</td>
<td>k</td>
<td>days</td>
</tr>
<tr>
<td>Establishment</td>
<td>10-20</td>
<td>0.2</td>
<td>15-25</td>
</tr>
<tr>
<td>Vegetative</td>
<td>25-35</td>
<td>0.2</td>
<td>25-40</td>
</tr>
<tr>
<td>Flowering</td>
<td>30-40</td>
<td>0.8</td>
<td>15-20</td>
</tr>
<tr>
<td>Yield formation</td>
<td>30-35</td>
<td>0.6</td>
<td>35-45</td>
</tr>
<tr>
<td>Ripening</td>
<td>10-20</td>
<td>0.2</td>
<td>10-15</td>
</tr>
<tr>
<td>Total period</td>
<td>115-140</td>
<td>1.1</td>
<td>100-145</td>
</tr>
</tbody>
</table>
Given these growth phases and considering the fact that crops may fail because of drought during a relatively short period, IRI used a 3 phase contract structure. The contracts, developed for Malawi, Tanzania and Kenya, take a fairly straightforward approach. They are based on measured rainfall. The start of the growing season is determined by a sowing window and a sowing requirement (in mm/dekad). If this requirement is met, the growing season is assumed to start and the crop is supposed to go through 3 growth phases of predefined length: (1) vegetative, (2) flowering and (3) yield formation. Each phase is assigned a length in dekads, as well as a strike and an exit, expressed in mm precipitation. Below the strike partial payout starts. When the exit is reached payout is full and the contract is terminated. The payouts of different phases are added up to a maximum of 100% of the insured sum.

The IRI contract structure is an effort to more closely represent the phenology of crop development and to address the effects of drought in the different stages of crop development as experienced by the farmers. At the same time this contract structure is exposed to new limitations, which are less in a single phase, i.e. total growing season contract.

In the case of maize, for example, a standard phasing of the growing season could be: vegetative: 5, flowering: 3, and yield formation: 5 dekads. Since during flowering the crop is most sensitive to drought, and since the flowering phase is relatively short, the outcome of the contract becomes critically dependent on the accurate timing of the start of the growing season. Our analysis indicates that the standard crop calendars used by FAO and USDA are not accurate in this respect and that the actual start of the growing season may vary considerably from year to year and from place to place. Since it is our objective to provide drought insurance that can be scaled up easily, we have developed a more general approach to locate the growing season, based on the Meteosat historic RE data series.
5.2 Timing the growing season

Farmers grow their crop during the period that, on the basis of experience and tradition, is known to provide the best conditions for crop growth. We will reproduce the development of such indigenous knowledge by analysing the full historic data series and identifying the periods which provide the highest water availability to grow a crop. In this example we will address the timing of maize growth, which has a growing season of about 130 days. The analysis is done in the following steps:

- Calculate the 130 day forward floating RE average,
- Find the yearly maximum in the 130 day forward floating RE,
- Determine the corresponding start of season dekad,
- Determine the frequency distribution of all growing season starts,
- Determine the 10 and 90 percentile as earliest and latest start.

An example of the result of the first step was already shown in figure 4.5, which presents the 24 year time course of the 130 day forward floating average of relative evapotranspiration and precipitation. The maxima in these curves are well defined and may be extracted for each year. In this way we may determine the frequency distribution of the start of the growing season at all locations.

5.3 Start of growing season window

Figures 5.3 to 5.6 present the frequency distribution of the growing season start for the relative evapotranspiration (RE) and precipitation (PREC) data at two contrasting locations: Mbeya in the southwest and Moshi in the north of the country. There is a phase shift between the RE based and the PREC based starts. In this respect it is noted that the PREC based start would indicate sowing, while the RE based reflects the start of vegetative growth. We may subsequently define a start of season window by taking the 10- and 90-percentile of all starts as begin and end of that window, respectively. The resulting RE based starting window for all stations is shown in figure 5.2, below.

![Figure 5.2: Calculated start of season window for 21 locations in Tanzania.](image)
There are apparently two regimes: one with the dominant start during the last two months of the year (dekad 30-36) and one during the first 3 months of the year (dekad 37-48, i.e. 1-12). The first period applies to the west and south of the country, the second period applies to the north-east of the country.

5.4 Triggering the growing season start

When the insurance is actually running, the future development of the index is not yet known and the actual start of the season cannot be determined on the basis of a 130 day forward average. Therefore a different criterion has to be used to trigger the actual start of the season. For the actual start to occur, a minimum relative evapotranspiration i.e. soil water availability is required, within the limits of the starting window. The trigger RE ≥ 65% has appeared to work well in practice. This threshold roughly corresponds to a soil moisture tension of -10 J/kg, equivalent to soil moisture at “field capacity”. For the corresponding PREC start of season we use an equivalent precipitation level calculated as 65% of the potential evapotranspiration during a dekad, i.e. 0.65*10*5=35 mm/dekad.
We may hereafter determine the frequency distribution of the simulated actual starts. The results for Mbeya and Moshi are shown in figures 5.7-10. For Mbeya both the RE and PREC based starts fall in a short period of one month: dekad 33-35. For Moshi there is a considerable difference, with the PREC based starts in dekad 2-8 and the RE based starts in dekad 7-11.

The possibility exists that the starting criterion is not met within the starting window period. Then there is the option to either start the growing season in the last dekad of the starting window, or to give a payout and terminate the coverage.

### 5.5 Calculating growing season payout

In a multi-phase growing season structure, payout is calculated at the end of each phase. Ideally this payout should be identical to the fraction of yield lost due to drought in that phase. The fraction lost may be expressed in terms of yield (Y) as well as relative yield (\(RY = Y/Y_{\text{max}}\)), as the maximum yield is considered a constant. In view of the SDK relation (23) we will use the relative yield. Indemnification of yield loss is usually expressed relative to a strike level \(RY_s\), as the first loss (1- \(RY_s\)) is not covered. Indemnification starts at the strike level and is assumed complete at the exit.
level ($RY_e$), which recognizes that at a certain level of loss it is not economic anymore to harvest. So the actual pay-out in phase $i$ ($PO_i$), expressed as a fraction or percentage of the insured sum, is then formulated as:

$$PO_i = \frac{RY_s - RY_i}{RY_s - RY_e} \quad (24)$$

Here $RY_i$ is actual yield pertaining to phase $i$. With the SDK equation (23), the relative yields $RY_s, RY_i$ and $RY_e$ may be expressed in the corresponding phase averaged $RE$ levels: $RE_s, RE_i, RE_e$. These expressions may subsequently be substituted in the previous equation (24), leading to the following expression of the payout in terms of relative evapotranspiration levels:

$$PO_i = \frac{RE_s - RE_i}{RE_s - RE_e} \quad (25)$$

The previous shows that a payout calculation on the basis of relative evapotranspiration levels is fully consistent with one based on yield losses. Frequently, drought insurance serves to cover a loan from which the farmer finances his cumulative investment in agricultural inputs. In such case a coverage level ($CO_i$) may be introduced additionally, which expresses the fraction of the loan that at the end of each phase has been used. Then the payout becomes:

$$PO_i = CO_i \times \frac{RE_s - RE_i}{RE_s - RE_e} \quad (26)$$

The total payout at the end of the growing season ($PO_t$) is obtained by summing up the individual payout in each phase, but limited to a maximum of 100%:

$$PO_t = PO_1 + PO_2 + PO_3 \quad (PO_t \leq 100\%) \quad (27)$$

The index design may additionally provide the option of payout on a failed start of the season ($PO_0$). In such case it may be assumed that the crop is lost, leading to a full payout, which is to be multiplied with a corresponding coverage level $CO_0$. In such case the insurance is terminated and further payouts are cancelled. So:

$$PO_1 = PO_2 = PO_3 = 0$$
$$PO_t = PO_0 = CO_0 \quad (28, 29)$$

Alternatively, if the failed start option has not been set, but the end of the starting window is reached, the growing season is assumed to start in the last dekad of that window. A possible late start of the season will then have its influence on the payout at the end of the first phase.

### 5.6 Setting strike and exit

When dealing with multiple locations, differing in local climatic conditions, there are three different ways of setting the strike and exit for a given phase, as discussed in the following sub-sections. From the historic data series the average relative evapotranspiration is obtained for each phase ($RE_{avg}$), even if this phase has a dynamic start, as discussed in sections 5.2-4. This average relative evapotranspiration represents the quality of crop growth during that phase.
5.6.1 Agronomic approach

In the agronomic approach, the strike and exit are set as a fraction of the growing season average relative evapotranspiration:

\[
\begin{align*}
RE_s &= A \times RE_{avg} \\
RE_e &= B \times RE_{avg}
\end{align*}
\]

(30)

(31)

A and B are index insurance parameters that are to be determined during insurance design. In this approach, differences in exposure to climatic dryness will lead to corresponding differences in payout and consequently in the premiums to be paid. On the other hand, farmers in dryer areas may grow more drought resistant crop varieties and may not experience more frequent crop failure. In addition and from a viewpoint of administrative burden, it may not be desirable to have a large variation in insurance pricing. Therefore there are also alternative ways of setting the strike and exit.

5.6.2 Standard deviation approach

In this approach the strike and exit are expressed in terms of the standard deviation from average:

\[
\begin{align*}
RE_s &= RE_{avg} - C \times \sigma_{RE} \\
RE_e &= RE_{avg} - D \times \sigma_{RE}
\end{align*}
\]

(32)

(33)

Here \( \sigma_{RE} \) is the standard deviation of the historic phase averaged \( RE \) values. C and D are index insurance parameters to be chosen during design. This approach assumes that local agriculture is adapted to the local \( RE \) average and that payments should be related to the deviation from the local average. The expression of the strike and exit, in terms of average and standard deviation, tends to normalize the payout in the case of a more or less normal distribution of \( RE \). Therefore in this approach payouts will be more similar, but will not be the same. For example, skew distributions in which low \( RE \) values are over-represented will show higher burning costs and thus a higher pure risk premium.

5.6.3 Percentile approach

In this approach, the strike and exit are determined as the X and Y percentile of the historic set of phase averaged \( RE \) values:

\[
\begin{align*}
RE_s &= X\text{-percentile of } \{RE_i\...\} \\
RE_e &= Y\text{-percentile of } \{RE_i\...\}
\end{align*}
\]

(34)

(35)

X and Y are index insurance design parameters to be chosen during design. The advantage of the percentile approach is that the calculated payout will be almost the same everywhere. This is simple in terms of administration as the premium would be everywhere the same.

In the percentile approach, the premium would not reflect differences in drought risk. This problem may be overcome, however, by creating a set of insurance designs with different percentile setting and thus a different payout and corresponding premium.
level. The farmer could than make a choice from this set of products according to his perception of the drought risk and his willingness to pay.
6 COMPARING RE AND PRECIPITATION BASED INSURANCE DESIGN

We have implemented the 3-phase index insurance contract structure, as proposed by Osgood et al. (2007) and discussed in the previous chapter, in an Excel Workbook and we have carried out a comparative historic payout analysis using the data for the 21 locations in Tanzania, which were already discussed in chapter 4. However, contrary to the approach in the previous reference, the start of the growing season is location specific and dynamic, as discussed in sections 5.2-4.

6.1 RE and PREC based payout for a standard 3 phase structure

An overview of the workbook set-up and calculations is presented in table 6.1. The input for the calculations include: start of season trigger, length of the three growing phases, strike percentile, exit percentile, and precipitation cap. As discussed earlier a start of season trigger of $RE \geq 65\%$ is applied. The corresponding rainfall requirement is set at $PREC= 0.65 \times 10 \times 5 = 35$ mm/decad. In addition a precipitation cap of 50 mm/decad was applied, which is about equal to the potential evapotranspiration.

Table 6.1: Workbook set-up used to carry out a historic payout simulation.

<table>
<thead>
<tr>
<th>Spreadsheet</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Basic data set:</td>
</tr>
<tr>
<td></td>
<td>• Dekad RE and PREC data by location in columns.</td>
</tr>
<tr>
<td></td>
<td>Parameters:</td>
</tr>
<tr>
<td></td>
<td>• Season trigger for RE (%) and PREC (mm/decad).</td>
</tr>
<tr>
<td></td>
<td>• Length of phase 1 (vegetative) in dekads.</td>
</tr>
<tr>
<td></td>
<td>• Length of phase 2 (flowering) in dekads.</td>
</tr>
<tr>
<td></td>
<td>• Length of phase 3 (yield formation) in dekads.</td>
</tr>
<tr>
<td></td>
<td>• Payout trigger percentile.</td>
</tr>
<tr>
<td></td>
<td>• Payout exit percentile.</td>
</tr>
<tr>
<td></td>
<td>• Precipitation cap.</td>
</tr>
<tr>
<td>Season starting window</td>
<td>• Calculate growing season forward floating RE/PREC averages.</td>
</tr>
<tr>
<td></td>
<td>• Determine maximum values of 130-day RE/PREC, and corresponding growing season yearly start.</td>
</tr>
<tr>
<td></td>
<td>• Determine starting dekad frequency distribution and mode.</td>
</tr>
<tr>
<td>Season start</td>
<td>• Test within sowing window the RE/PREC starting condition.</td>
</tr>
<tr>
<td></td>
<td>• Find actual growing season start dekad.</td>
</tr>
<tr>
<td></td>
<td>• Calculate payout on failed start (if applicable)</td>
</tr>
<tr>
<td>Phase-1</td>
<td>• Calculate forward floating phase average of RE/PREC.</td>
</tr>
<tr>
<td></td>
<td>• Extract RE/PREC phase-average for each year, given that years growing season start and phase length.</td>
</tr>
<tr>
<td></td>
<td>• Calculate the RE/PREC strike and exit from the corresponding percentiles, given the phase averaged values in each year.</td>
</tr>
<tr>
<td></td>
<td>• Calculate payouts as: coverage*(phase strike – phase average)/(phase strike – phase exit).</td>
</tr>
<tr>
<td>Phase-2</td>
<td>Idem.</td>
</tr>
<tr>
<td>Phase-3</td>
<td>Idem.</td>
</tr>
<tr>
<td>Summary results</td>
<td>• Sum-up phase payouts and calculate total payout up to a maximum of 1.00, i.e. the insured sum.</td>
</tr>
<tr>
<td></td>
<td>• Sum payouts by location and calculate location averages.</td>
</tr>
</tbody>
</table>
For the reference design (case 1) a maize growing season of 130 days is assumed with 3 phases of 5/35/5 dekads. Payouts are possible at the end of each phase. In all phases strike and exit are set at the 4 and 1 percentile level, respectively. If the growing season fails to start a full payout is assigned and coverage is terminated. In addition coverage levels can be assigned to each payout event. They reflect the cumulative level of investment as a fraction of the insured sum. In the present example coverage levels have simply been set to 1. Cumulative payouts are restricted to 100% of the insured sum.

Payout simulations have been carried out for maize during the period 1984-2007. Payout numbers and values in percent are summarized in table 6.2. In the column “Same PO” the percentage number of events that RE and PREC give simultaneous payout is shown. Case 1 in this table is the reference case. The other cases represent variations as specified in the table. Figures 6.2-5 show the RE and PREC based payouts by year (6.2-3) and by location (6.4-5). The bars of these graphs show in colour how much of the payout originates from failed starts (blue), phase 1 (red), phase 2 (green) and phase 3 (violet). Average payout is much higher for the PREC data (23.5%) than for the RE data (12.8%). There is fair agreement on the worst years: 1988, 1997, 1999, 2000, 2003 and 2006. There is also a fairly good correlation ($R^2=0.87$) between the RE and PREC based payouts (figure 6.1).

Table 6.2: Payout characteristics for several trigger percentiles and growing season phasing structures. Start of growing season is automatic. Exit at 1-percentile level.

<table>
<thead>
<tr>
<th>Case</th>
<th>Phases</th>
<th>Failed Start?</th>
<th>Strike Perc.</th>
<th>RE</th>
<th>PREC</th>
<th>Same PO</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RE</td>
<td>PREC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,3,5</td>
<td>+</td>
<td>4</td>
<td>59</td>
<td>12.8</td>
<td>108</td>
<td>23.5</td>
</tr>
<tr>
<td>2</td>
<td>5,3,5</td>
<td>+</td>
<td>8</td>
<td>106</td>
<td>17.5</td>
<td>156</td>
<td>27.3</td>
</tr>
<tr>
<td>3</td>
<td>5,3,5</td>
<td>+</td>
<td>16</td>
<td>190</td>
<td>24.0</td>
<td>225</td>
<td>34.6</td>
</tr>
<tr>
<td>4</td>
<td>5,3,5</td>
<td>-</td>
<td>4</td>
<td>52</td>
<td>11.3</td>
<td>51</td>
<td>11.1</td>
</tr>
<tr>
<td>5</td>
<td>5,8</td>
<td>+</td>
<td>4</td>
<td>47</td>
<td>10.2</td>
<td>97</td>
<td>21.1</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>+</td>
<td>4</td>
<td>28</td>
<td>6.1</td>
<td>78</td>
<td>20.7</td>
</tr>
</tbody>
</table>

Figure 6.1: Correlation between RE and PREC based yearly payouts during the period 1984-2007.
Figure 6.2: RE payout by year for a 5,3,5 dekad structure, strike=4p (case 1).

Figure 6.3: PREC payout by year for a 5,3,5 dekad structure, strike=4p (case 1).

Figure 6.4: RE payout by location for a 5,3,5 dekad structure, strike=4p (case 1).

Figure 6.5: PREC payout by location for a 5,3,5 dekad structure, strike=4p (case 1).
6.2 Variations in strike and phasing

The large difference between the RE and PREC based payouts is mainly caused by the payout on failed start. Note the blue bars in figures 6.2 and 6.3. Particularly for the precipitation data the payouts on failed start are very high. This may be due to the more erratic nature of precipitation data, while the RE data are more smooth because of the buffering action of the soil. The workbook has the option to turn off the failed start mechanism. In that case the ultimate season starting dekad is the last dekad of the starting window. If this option is used RE and PREC based payouts become as shown in figures 6.6 and 6.7, respectively. The average payout in both cases is almost the same and about 11% (table 6.2, case 4).

Figures 6.8 and 6.9 show how an increase of the RE strike levels to the 8 and 16 percentile affects the payout results (table 6.2: case 2 and 3). The burning costs increase from 12.8% to 17.5% and 24%, respectively. Of course this increases the premium as well. The premium may be reduced again by applying an appropriate coverage to each phase, in line with the cumulative level of farmer’s expenditure on inputs.

There are two additional cases that show the effect of changes in growing season phasing (table 6.2, case 5 and 6). Figures 6.10 and 6.11 present the payout profile for a 5/8 dekad and a 13 dekad growing season structure, respectively. As the number of occasions for payout reduces, burning costs go down as well: from 12.8 to 10.2 and 6.1 percent respectively.

![Figure 6.6](image1.png)

Figure 6.6: RE reference case (figure 6.2) but without failed start (case 4).

![Figure 6.7](image2.png)

Figure 6.7: PREC reference case (figure 6.3) but without failed start (case 4).
Figure 6.8: RE payout by year for a 5,3,5 dekad structure, strike=8 percentile (case 2).

Figure 6.9: RE payout by year for a 5,3,5 dekad structure, strike=16 perc. (case 3).

Figure 6.10: RE payout by year for a 5,8 dekad structure, strike=4 percentile (case 5).

Figure 6.11: RE payout by year for a 13 dekad structure, strike=4 percentile (case 6).
6.3 Discussion

Usually in Tanzania two rainfall seasons are discerned (see figure 4.6): the Vuli or short rains season (November, December, January) and the Masika or long rains season (March, April, May). In the northeast the Vuli rains tend to be minor and there is usually only the Masika growing season. In the middle, south and west of the country the rains start already in November and there is one long season or there are two shorter consecutive growing periods.

In the preliminary insurance design and burn study, presented in the previous section, the crop growing period was not narrowed to one of these seasons. The start was determined at the first possible occasion that the starting condition was satisfied and subsequently a maize growing season of 130 days was assumed. This implies that at some of the locations the maize “grew” already during the Vuli season, while at other locations, particularly in the north-east, start and growing period did better correspond with the Masika season. Therefore in this investigation the simulated overall burning costs are related to a mixture of Vuli and Masika growing periods. In an actual index design the start of season window may be narrowed down and more tuned to the specific area and growing period, in consultation with the client.

Despite these complications due to a bimodal precipitation regime, there is a fairly good correspondence between the satellite based relative evapotranspiration and the surface rainfall based payouts. For the reference case (130 day, 3-phases), with 12.8% payout, there is a good correlation with $R^2=0.873$ (figure 6.1).

We would like to support our observations on drought years and related payout with additional evidence. Information on the web on drought disasters is fuzzy and there are several pitfalls. The years we attach to our payout results refer to the year of harvest. The drought that causes crop failure and low harvest may however have struck during the Vuli season and for this reason may be remembered as taking place in the previous year. In addition there are different types of drought related information: rainfall deficits, production decreases, food shortages, import requirements. Quite often they are rough, first estimates.

We have tried to obtain a spatial perception of the droughts that have taken place. Maps of the difference evapotranspiration (DE) have been prepared for drought years with major payouts: 1994, 1997, 1999, 2000, 2003 and 2006. They are presented in table 6.3. Here, the difference evapotranspiration (DE) is the difference between the growing season average relative evapotranspiration (RE) in the current year and the corresponding average of the previous 10 years ($RE_{10yr}$). These DE-maps are presented for both the Vuli season (Nov-Jan) and the Masika season (March-May) in table 6.3. Below each map we have added related citations found on the web. In general the presented information is consistent with the payouts as determined in the previous section.

However there is one, on first sight puzzling season. In figures 6.8 and 6.9 we observe the highest payout in 2003. Nevertheless 2003 seems not an extremely dry year in the corresponding maps of table 6.3, page 56. Only the Masika season shows some drought (red colour) in the mid and northeast of the country. However the 2003 drought seems much less than the Vuli drought of 2006. Nevertheless FAOSTAT data show a fall in cereal yield to 50% below average.
We have studied this apparent contradiction. Figure 6.12 shows the course of the relative evapotranspiration during the second half of 2002 and the first half of 2003 (red line) as well as the climatic average (blue line) at Arusha in the north of the country. The Vuli and Masika seasons are indicated. It is clear from this graph that the 2002/03 Vuli season was above average and this observation corresponds to the related map in table 6.3 on page 56. However, the Masika season started rather late and saw an extremely dry spell during dekad 11-13 with RE around 30%. Such low RE indicates below wilting soil moisture tension and during such period would completely eradicate a maize crop and give full payout. Here we observe that a relatively short dry spell may be sufficient to destroy a crop, while this may not be so clear from the growing season average RE value or map, as presented in table 6.3 for the 2003 Masika season. This has happened in 2003 and caused a reduction in cereal yield of ~50% below average. This is the very argument for the use of a phased growing season structure in index insurance. With a 13 dekad single phase structure the 2003 crop failure and payout would be underestimated and this is also clear from the low 2003 payout in figure 6.11.

Summarizing it may be concluded that the evidence presented in table 6.3 on the next three pages confirms the outcome of the RE based drought insurance design presented and discussed earlier in this chapter.

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Figure 6.12: Course of the relative evapotranspiration drought index (RE) at Arusha in north Tanzania during the second half of 2002 and first half of 2003. The Masika season starts late and shows a 3 dekad dry spell in the middle.
Table 6.3: Evidence of drought and crop failure in several drought years. Maps show the difference evapotranspiration, scaled from -30% (black=below average) to +30% (blue=above average). Below these maps related information from the world wide web is presented.

2006

<table>
<thead>
<tr>
<th>Source</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEWS</td>
<td>18/2/06</td>
<td>Prolonged drought and failure of 2005/6 vuli rain season. 85% of Tanzania affected. 3.7 million people facing food shortage, 567000 people need emergency food supplies.</td>
</tr>
<tr>
<td>Red Cross</td>
<td>3/3/06</td>
<td></td>
</tr>
</tbody>
</table>

2003

<table>
<thead>
<tr>
<th>Source</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afrol news</td>
<td>24/5/03</td>
<td>Rainfall low and erratic in 2002/3 production year. Food production declined by 10% from 8.6 to 7.7 Mton.</td>
</tr>
<tr>
<td>IRIN</td>
<td>3/10/03</td>
<td>85% of maize, sorghum and groundnuts affected by drought in N-Tanzania. 2 Million people facing food insecurity.</td>
</tr>
<tr>
<td>FAO</td>
<td>15/10/03</td>
<td>Prolonged drought in several areas, 1.9 million people needing food, 1.6 million needing emergency assistance.</td>
</tr>
</tbody>
</table>
Table 6.3 continued.

<table>
<thead>
<tr>
<th>Year</th>
<th>Season 1</th>
<th>Season 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Vuli</td>
<td>Masika</td>
</tr>
</tbody>
</table>

FAO/GIEWS 18/4/00 Cereal crop 4 Mton: 8% below previous year, due to erratic rains. 800,000 people food insecure, due to third poor harvest.

FEWS NET 15/9/00 Drought and reduced harvest in central and northern regions. 1.3 million people food insecure. 75000 ton food aid needed.

1999

<table>
<thead>
<tr>
<th>Year</th>
<th>Season 1</th>
<th>Season 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Vuli</td>
<td>Masika</td>
</tr>
</tbody>
</table>

FAO/WFP 15/2/99 Vuli rains delayed. Maize production 60% lower. Import requirements 480,000 ton.

Africa News Online 16/12/99 1999 cereal production: 3.76 Mton, 10% below 1998. Import need: 600,000 ton.
Table 6.3 continued.

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>Vuli</td>
<td>3 Million Tanzanians facing food shortage. 916000 ton needed. Drought affects 65% of country. 40% of population facing famine. Hardest hit areas in the north.</td>
</tr>
<tr>
<td>1994</td>
<td>Masika</td>
<td>Horn of Africa facing another famine. 22 million people threatened.</td>
</tr>
<tr>
<td>1993/4</td>
<td>Chang’a</td>
<td>Power shortages because of drought. 21% fall in maize, 36% in wheat production. Deficit 413000 ton.</td>
</tr>
</tbody>
</table>
7 EXCESSIVE PRECIPITATION INSURANCE DESIGN

High rainfall in Africa is brought by large convective Cumulonimbus clouds, which have very high cloud tops reaching to the tropopause. Such cloud systems are recognized from their very low cloud top temperatures, usually less than 226 K (table 2.1). High rainfall is associated with the presence and duration of such cold clouds. Therefore the Cold Cloud Duration (CCD) is a good indicator of total precipitation from such rain storms. The CCD is expressed as a percentage of the time period considered, in this case a dekad.

In Cumulonimbus clouds systems there are strong vertical movements that transport water vapour from the lower troposphere to higher levels, where the vapour condenses into clouds, aggregates to larger water droplets and finally precipitates. The stronger these vertical movements, the higher vertical vapour transport, cloud tops and rainfall intensity. We can measure the height of the cloud tops from their temperature. Higher cloud tops have lower temperature and are associated with higher rainfall intensity. The Temperature Threshold Excess (TTE) is the difference in Kelvin between the cold cloud threshold (226 K) and the actually measured cloud top temperature. This difference is determined every hour and averaged for a day. As daily data are not practical when working with 30 year of data, the maximum TTE during a dekad is used as an alternative indicator.

Figure 7.1: Climatic average of the cold cloud duration (CCD) over Africa.
Figure 7.2: Time series of the dekad cold cloud duration (CCD) in Dande, West Burkina.

Figure 7.3: Time series of the dekad temperature threshold excess (TTE) in Dande, West Burkina.
Summarizing we have from Meteosat the following 2 indices
- CCD, an indicator of total rainfall amount and related water logging and flooding.
- TTE, an indicator of extreme rainfall intensity and related mechanical damage.

For the purpose of excess rainfall insurance these satellite based indices may be appropriate. What matters in the first place is the detection of extreme events, and not so much the precise amount of rainfall.

The CCD and TTE indices have the advantage of being readily available from Meteosat for the entire continent and to be independent of scarce rain gauge data measured on the ground. The climatic average distribution of the cold cloud duration over Africa is shown in figure 7.1. In the east of the Congo the average reaches values up to 15% of the time. In the semi-arid zone the average is 3-5% of the time.

7.1 Burkina Faso trial

On a trial basis, simple excessive precipitation insurance was designed for 4 locations in the west of Burkina Faso. The time series of the CCD and the TTE were extracted for the period 1982-2010. These time series at Dande are shown in figures 7.2 and 7.3. Figure 7.2 shows that CCD’s larger than 14 or 15% occur only a few times during the entire period and can easily be identified.

The last two major excessive rainfall events occurred during the second dekad of August 2003 and the first dekad of August 2007. See the CCD “spikes” in figure 7.2. A CCD map of the last event is presented in figure 7.4. While drought is a gradual event, leading to reduced crop yield, the effect of excessive precipitation is immediate and often leading to a full loss. The initial index insurance design could therefore be simple: if the CCD is larger than 15% during a single dekad, full payout is assumed. The result of a corresponding historic payout simulation is shown in figure 7.5. In 2003 a payout of 100% and in 2007 of 75% would have taken place.

On the web (e.g. www.reliefweb.int) one may find confirmation. In 2003 IFRC reported: “In Burkina Faso, the heavy rainfalls flooded 10 major towns of the country and created an emergency situation for over 3,000 families. Some 900 families lost their homes and belongings, local food stocks were destroyed, and many crops were inundated, jeopardizing the next harvest”. Also the excessive rainfall event in August 2007 caused a crisis. The UN Office for the Coordination of Humanitarian Affairs reported: “A humanitarian crisis may be emerging in Burkina Faso with rains destroying people’s homes and farmland in several areas across the country (...) On 5 August two-thirds of all houses in the village of Ban were washed away after rain fell non-stop for 13 hours”.

Figure 7.4: CCD map of a major excessive precipitation event in Mali and Burkina Faso during the 1st decade of August 2007. Scale: 0-20%.

Figure 7.5: Excessive precipitation payout by year (above) and by location (left) for 4 locations in West Burkina Faso during the period 1982-2010. Strike at CCD>15.
8 PILOT PROJECTS

After development of the satellite derived RE index database and the index design approach, as discussed in the previous chapters, several pilot projects have been carried out during the years 2011-2013, in close cooperation with partners that are active as micro-insurance broker in Africa. Categories of stakeholders that play a role in these pilot projects are depicted in figure 8.1. Besides the micro-insurance broker, one or more local insurers and a re-insurer are involved.

Crop micro-insurance projects are carried out in 3 phases: (1) design, (2) sales and (3) monitoring. EARS, is mainly involved in the design and monitoring phases, providing the following services.

In the design phase:
- Provide historic index data series for each location/community to be insured.
- Develop the insurance index structure and carry out a simulation of historic payouts so as to determine the “burning costs” or “pure risk premium”.
- Provide the design to broker, insurer, and re-insurer for approval and pricing.

In the monitoring phase:
- Receive and process Meteosat data to RE indices.
- Analyze index performance and payout.
- Report every 10 days to broker and (re-)insurer.

At the end of the design phase the index insurance is priced by the (re-)insurer. Hereafter the insurance is to be sold. This is usually done by the broker. But also the local insurance company will use its network to contribute to sales activities. Direct sale to individual farmers has appeared to be a difficult business model. Therefore aggregators should be involved. These could be farmer unions or supporting NGO’s, but also parties that have a complementary commercial interest, such as credit providers, input providers, or processing industries.

Figure 8.1: Scheme of the index insurance service chain.
Table 8.1: Overview of the main FESA Micro-insurance pilot projects carried out in the period 2011-2013.

<table>
<thead>
<tr>
<th>Partner / broker</th>
<th>Countries</th>
<th>Period</th>
<th>Crop</th>
<th>Peril</th>
<th>Insurer(s)</th>
<th>Re-insurer</th>
<th>Aggregators</th>
<th>Co-financing framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>PlaNet Guarantee</td>
<td>Burkina, Mali, Benin</td>
<td>2011-13</td>
<td>maize, cotton</td>
<td>drought, excessive precipitation</td>
<td>Allianz</td>
<td>Swiss Re</td>
<td>IFC-GIIF, AECF</td>
<td></td>
</tr>
<tr>
<td>PlaNet Guarantee</td>
<td>Kenya</td>
<td>2012-13</td>
<td>cotton, sorghum</td>
<td>drought</td>
<td>APA, Jubilee</td>
<td>Swiss Re</td>
<td>Rift Valley Products, AECF</td>
<td></td>
</tr>
<tr>
<td>Syngenta Foundation</td>
<td>Kenya</td>
<td>2011-12</td>
<td>French beans</td>
<td>drought, excessive precipitation</td>
<td>UAP</td>
<td>Swiss Re</td>
<td>Frigoken, IFC-GIIF</td>
<td></td>
</tr>
<tr>
<td>FSD Kenya</td>
<td>Kenya</td>
<td>2011-12</td>
<td>wheat, maize</td>
<td>drought</td>
<td>APA</td>
<td>Swiss Re</td>
<td>AFC, Equity Bank</td>
<td>Rockefeller Foundation, World Bank</td>
</tr>
<tr>
<td>COIN-Re</td>
<td>Malawi, Mozambique</td>
<td>2012-13</td>
<td>maize</td>
<td>drought</td>
<td>Universal Corporation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARC</td>
<td>Uganda</td>
<td>2013-1</td>
<td>maize, livestock</td>
<td>drought</td>
<td>Lion Assurance Co.&amp; 7 others</td>
<td>Swiss Re</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRA</td>
<td>Botswana</td>
<td>2013-1</td>
<td>sorghum</td>
<td>drought</td>
<td>HRA</td>
<td>Swiss Re</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IFAD/WFP</td>
<td>Senegal</td>
<td>2013-1</td>
<td>several</td>
<td>drought</td>
<td>HRA</td>
<td>Swiss Re</td>
<td>IFC-GIIF</td>
<td></td>
</tr>
</tbody>
</table>

*) Dutch Government contributing to all projects through present millennium project.
FESA Micro-Insurance: Crop insurance reaching every farmer in Africa

Figure 8.2: Location of 12 communities in Burkina Faso and Mali for which the first drought insurance was designed.

Table 8.1 provides an overview of all project partners involved in the piloting phase of the FESA project. The table also indicates the insurers, re-insurer and aggregators involved, as well as the possible co-financing framework supporting the project partners.

8.1 Drought insurance for maize growers in Mali, Burkina Faso and Benin

Since March 2010 EARS has been cooperating with Planet Guarantee in the GIIF project Regional Strategy for the Implementation of Index-based Crop Insurance in Western Africa.

The first drought index insurance was developed end 2010 and early 2011 for 4 communities in west Burkina Faso and 8 in the east of Mali. Their location is shown in figure 8.2, superimposed on a map of the 2011 growing season average RE. The area is characterized by a unimodal rainfall regime. The RE data have a very strong seasonal variation. This is clear from figure 8.3 which presents the historic RE data series at Dande. Every year the RE values vary as much as from 10 to 100%.

Figure 8.3: Temporal variation of the dekad RE at Dande, Burkina Faso.
The starting window was derived on the basis of the probability of growing season start, as derived from the historic RE data series and determined as dekad 14-21 in Burkina (figure 8.4) and dekad 12-21 in Mali. A growing season starting trigger of $RE \geq 65$ was applied to trigger the actual start. Based on information from the principal, the growing season was initially split up in two phases of 5 and 7 dekads, respectively. Strike and exit were determined on the basis of historic average and standard deviation: Strike = Avg - 1.2*StD and Exit = Avg – 3.3*StD. The design was discussed and adjusted in consultation with the stakeholders involved. Information from the field suggested the first phase to be most critical. Because of this consideration and to reduce the premium, the pilot was run for the first phase only. This implied burning costs of 3.24% in Burkina Faso and 2.9% in Mali. The distribution of the historic payouts by year and community is shown in figures 8.5-7.

The drought insurance was subsequently priced by Swiss Re and was sold to a very limited number of farmers. During the subsequent growing season, Meteosat data were received and processed and the resulting RE index was monitored. Results were reported every 10 days to broker and re-insurer. Towards the end of the growing season and after expiry of the drought coverage period, payouts were calculated and the final report was submitted. At the end of the 2011 growing season, the average payout was 2.5% in Burkina and 8.6% in Mali. For validation purposes, PlaNet Guarantee measured precipitations at several locations in the field. Based on these data it was concluded that the RE index captured the risk properly.

Early 2012, PlaNet Guarantee and the GIIF launched the first regional management platform for index insurance in West Africa, with an office in Dakar, Senegal. EARS is one of the consortium partners. The aim is to cover at least 60,000 famers by the end of 2015. In 2012 the project was scaled up considerably. The index was redesigned for 843 communities in Burkina Faso, Mali and Benin. This time a 4/2/4 growing season phasing was implemented, as well as the possibility of payout on a failed start. Coverage levels for the failed start and the 3 phases were 0.3/0.75/1/1 respectively. To obtain a fairly uniform price, the strike and exit were for every community set at the local 5 and zero percentiles, respectively. This design resulted in average burning costs of 4.83% in Burkina, 4.54% in Mali and 5.59% in Benin. The distribution of historic payout by year and by community is shown for Mali in figures 8.8 and 8.9. In 2012 the number of farmers making use of the drought insurance grew to sixteen thousand. The growing season was monitored and reported every dekad. At the end of the growing season the payout was 24.7% in Burkina, 5.8% in Mali and 2.8% in Benin.
After the 2012 growing season the index insurance activities were discussed and evaluated during a meeting in Paris, October 2012. This included a comparison of RE, rainfall and area-yield based approaches. PlaNet Guarantee concluded that significant scaling up of the index insurance activities would only be possible on the basis of the RE index.

Figure 8.5: Simulated historic payout for the 4 locations in Burkina Faso.

Figure 8.6: Simulated historic payout for the 8 locations in Mali.

Figure 8.7: Simulated payout by community in Burkina (left) and Mali (right).
Figure 8.8: Historic average payout by year for 420 communities in Mali.

Figure 8.9: Historic average payouts by community for 420 communities in Mali.
8.1.1 Insurance scaling up

Figure 8.9, pertaining 420 communities in Mali, indicates that it becomes difficult to handle and illustrate the performance of an insurance design when the scale of the insurance increases. In 2012 the drought insurance design for West Africa included 843 communities, but in 2013 this number increased to 3732: 2165 communities in Mali, 887 in Burkina and 680 in Benin! This could no longer be handled in MS Excel. For this reason new insurance design tools were developed during the autumn of 2012 based on Structured Query Language and MS Access. The corresponding insurance design developed for the 2013 growing season was set-up very similar to that in 2012. Only the growing season phasing changed somewhat to 4/3/3. In addition for all three countries two designs were developed, one based on early sowing (dekad 17-19) and one based on late sowing (dekad 20-21), thus allowing for a more flexible approach to interested farmers and a longer continuation of sales.

Burning costs of all designs were in the 4.9-5.8% range. A spatial overview of the burning costs / pure risk premium is presented in figure 8.10. The insurance was priced by the reinsurer at 7%. This was considered a break-through and an indication of how increase of scale may lead to reduced loadings on the pure risk premium and the insurance becoming more affordable to farmers. Growing season payout was between 3.7 and 4.8%, except for the late sowing insurance in Benin, which saw an end of season payout of 13.1%.

Figure 8.10: Spatial overview of 1982-2012 average payout or “burning costs” for 3732 communities in Mali (left), Burkina Faso (middle) and Benin (right). Colours indicate the height of these costs and run from zero (blue) to 15% (dark red).
8.2 Drought and excess precipitation insurance for French bean growers in Kenya

Syngenta Foundation is developing agricultural drought insurance in East Africa, in particular in Kenya and Rwanda. The project is called Kilomo Salama (safe farming) and was launched in 2008. The project is financially supported by the GIIF. Kilimo Salama does not visit farms. The project uses automated weather stations and mobile payment. In the framework of the FESA Micro-insurance project, Syngenta Foundation and EARS have cooperated to explore Meteosat based horticulture insurance for drought and flood in the Kandara region in Kenya. Interested stakeholders were the insurers UAP and Jubilee, as well as processor Frigoken.

Insurance design took place during 2011. This design had to be quite different from the design developed earlier in Burkina and Mali for maize, which grows during a specific growing season. In Kandara, French beans are grown throughout the year: on average 6 crops per year. The beans are irrigated with water from small streams that run down the Kandara mountain range. Nevertheless there are drier seasons and sometimes these streams may also run dry, causing drought damage to the local horticulture. In this situation measured rainfall is certainly not a suitable index, as water drainage from the mountains will continue after the rains have stopped. The Meteosat based relative evapotranspiration, however, reflects soil water content and for this reason could be more suitable.

Figure 8.11 (left): Location of the Kandara French bean growing area, super imposed on a map of the RE climatic average. Dark blue areas to the west and north are the Kandara mountain range and Mount Kenya, respectively.

Figure 8.12 (below): French bean collection centres in the Kandara area for which drought and excessive precipitation insurance was developed.
8.2.1 Drought insurance

For index insurance design 7 locations in Kandara where chosen. They correspond to product collection centres of French bean processor Frigoken. Producers are usually not more than a few kilometres off. Given that local run off is the aggregated result of drainage from a larger area, RE data series were extracted as 3*3 pixel (~10*10 km) averages. Figures 8.11 and 8.12 give an impression of the location of the area and the collection centres, superimposed on a map of the climatic RE average. The historic course of the average RE at these locations is presented in figure 8.12. The RE index data show strong variation, corresponding to a bimodal rainfall regime. RE values vary between 10 and 90%. This bimodal regime is illustrated by the average seasonal course of the RE index, as shown in figure 8.13. There are two wet seasons, centred May/June and Nov/Dec. Although on this basis two growing seasons may be discerned, the French beans are grown throughout the year and not in a synchronous way. For this reason payouts are calculated on a dekad by dekad basis, and are then aggregated so as to allow for a half yearly or yearly payout.

![Figure 8.13: Historic course of the RE index in Kandara (1982-2011).](image)

![Figure 8.14: Kandara average yearly RE distribution, indicating two wet seasons centred in May-June (dekad 13-19) and November-December (dekad 31-36).](image)
As the production cycle of this crop is 2 months, a 6 dekad backward RE floating average was used as bean yield proxy and loss index. An example of the course of this loss index is shown in figure 8.15 for collection centre C. Drought years for this centre can be discerned at first sight, in particular 1984 and 2000. Strike and exit levels were set at the 10 and 2 percentile respectively. Accumulated yearly payouts smaller than 10% were not reimbursed. In this way the burning costs remained at a low level of 3.6% of the insured sum. The distribution of historic payouts is presented by year in figure 8.16 and by collection centre in figure 8.17.

Figure 8.15: 6-dekad average RE course at location C.

Figure 8.16 (above): Kandara historic drought payout by year.

Figure 8.17 (left): Kandara historic drought payout by collection centre.
The suitability of the RE index for the estimation of irrigation water availability and related French bean production losses is not self evident. We have therefore investigated this issue on the basis of available stream flow and bean production data.

First the dekad RE data have been compared with simultaneous flow measurements of the Maragua River during the period 1982-2010. The Maragua is the most nearby, metered river that is fed with water running down the Kandara mountains. The result is shown in figure 8.18. There is a fair correlation between RE and flow, particularly at low flow levels, up to 15 m³/s. This is important to note as it are particularly the low flow events that we want to detect.

A second approach for testing the validity of 6 dekad RE index is by comparing this index with monthly French bean production data as obtained from processor Frigoken for the period 2006-2009. Two figures are available: “planted weight” and “harvest weight”. From these two we have determined the yield per unit planted weight:

\[ \text{Yield} = \frac{\text{harvested weight}}{\text{planted weight}} \]

This yield has been compared with the 6 dekad RE index (figure 8.19). There appears to be a temporal shift between the reported yield and the RE data. This phase shift has been determined by finding the optimum correlation between the 6 dekad RE data and the reported yields. The result of this correlation is shown in figure 8.20. The highest correlation (R²=0.25-0.40) is found for phase shift of 3 months. Figure 8.21 presents the relation between average bean yield and 6 dekad RE, after application of the phase shift: yield = 2.2* RE. In this way bean yield losses may be estimated from the RE index.
Figure 8.19: Comparison of 6 dekad RE index (location B2) with registered French bean yield. Note the evident time shift between the data.

Figure 8.20: Correlation between 6 dekad RE and bean yield as a function of phase shift.

Figure 8.21: Regression of 6 dekad RE versus reported average bean yield.
8.2.2 Excessive precipitation insurance

For the same seven collection centres, as shown in figure 8.12, excessive precipitation insurance was designed, using the Meteosat derived cold cloud duration (CCD) as excessive precipitation index. This index represents the Cumulonimbus dwelling time in percent of time during a dekad. The data were extracted for the same period 1982-2010. The historic course of the average CCD is presented in figure 8.21. In this graph, extreme rainfall events can be identified as high peaks. The highest peak occurred during the first dekad of April 1997 and reached a value of 25%. Examples of the presence of such very cold clouds are shown in figure 8.23 by means of two Meteosat midnight thermal infrared images from that dekad.

![Figure 8.22: Average dekad cold cloud duration (CCD) at Kandara.](image)

![Figure 8.23: Meteosat derived midnight thermal infrared images showing Cumulonimbus rain storms over Kenya and the Kandara region, 4 and 7 April 1997.](image)

![Figure 8.24: Kandara monthly CCD at collection centre B1.](image)
For insurance design the historic CCD data were extracted as 3*3 pixel averages, centred around 7 collection centres. The design is aiming at monthly payout. To prevent that significant rain storms are split up on the edge of one dekad to the next, we have first determined a 2 dekad floating average. Subsequently these data are combined to monthly averages, which are used as CCD excessive precipitation index. The course of this monthly index for collection centre B1 is shown in figure 8.24. There is very little difference between the collection centres.

Strike and exits were determined for each collection centre as the 80 and 99.9 percentiles. Strikes and exits pertaining to the collection centres showed very little difference and were averaged, leading to a fixed strike of CCD=1.38 and a fixed exit of CCD=10.04. In between these two CCD levels the payout is increasing linearly from 0 to 100%. Subsequently a burn analysis was done. Monthly payouts were calculated for the entire period 1982-2011. The payout pattern (figure 8.25) closely follows that of the CCD, with a highest payout of 100% in April 1997. The average burning costs, during the entire period of thirty year, is 4.55%, with only small differences between the collection centres (figure 8.26).

After insurance design, both the drought and the excessive precipitation insurance were priced by Swiss Re. However, partner Syngenta Foundation was not able to sell the product to aggregator Frigoken, which considered the products too expensive.
Figures 8.24 and 8.25 show a pattern of first increasing and later decreasing rain storm activity. Besides the 100% pay-out in April 1997, the next growing season 1997/1998 is characterized by a series of payouts at the 20-60% level, equivalent to 1.9 times a monthly full payout. This period is associated with the strong 1997/98 El Niño, that brought heavy rainfall and widespread flooding to Kenya. There was heavy damage to food crops and coffee. According to FAO, maize yield fell by 33%. There was also heavy damage to roads, buildings, bridges, railway lines and other property, estimated by the World Bank at 11% of the GDP. Total losses in the agricultural sector were estimated at more than US$230 million.

We have tried to verify the CCD index by comparing it with ground data from Kandara. We have first compared the flow of the Maragua River with the dekad CCD values. The result is shown in figure 8.27. There is good co-incidence between high CCD and high flow events, usually with some delay of the flow. However the high CCD/rainfall events are shorter living. Flow tends to continue and decrease more gradually. Because of this behaviour the correlation is not high: $R^2=0.11$ (figure 8.28).

We have additionally explored the relation between the monthly CCD index and French bean production data obtained from processor Frigoken. One of these data, the “fraction of inputs not recovered”, is available for the years 2006-2009. Figure 8.28 shows the 4 year course of this fraction and of the monthly CCD.
In the last year (2009) there is an upward trend in the fraction not recovered. This trend may be attributed to the drought occurring during this year (figure 8.15). In addition we observe a phase shift in the fraction not recovered of about 3 months. If we take account of this phase shift, there is for the first three years (2006-2008) a fair relation between the fraction not recovered and the monthly CCD ($R^2=0.3$) as shown in figure 8.30.

8.3 Drought insurance for cotton farmers in Tanzania

In 2011 MicroEnsure was commissioned by the Tanzanian Cotton Board to develop weather insurance for cotton growers in Tanzania. A first pilot project was to be carried out in the Bunda district of Mara province. As there were insufficient reliable rain gauge data in this area, EARS was requested to develop an RE based drought index for 23 wards (departments) in the district. Their location, on the eastern side of Lake Victoria, is shown in figure 8.31.

Figures 8.32 and 8.33 present the RE time series at Kabasa and Guta, both more or less central in the Bunda district. The red line in these figures is the 15 dekad forward floating average. The RE patterns are quite chaotic, with sometimes suggestions of a bimodal regime. The seasonal variation is much less regular and extreme than in the Sahel region (figure 8.3). The maxima in the 15 dekad averages indicate the start and quality of the growing season. The growing season start is around the New Year. Striking is the downward trend at Guta (figure 8.32) while this trend is not present in Kabasa (figure 8.31). There are several locations showing a similar trend, while others do not.
Figure 8.31: Map of 2010 average RE, showing the location of 23 wards in Mara province, east of Lake Victoria.

Figure 8.32: RE course at Kabasa (blue) and 15-dekad forward average (red).

Figure 8.33: RE course at Guta (blue) and 15-dekad forward average (red).
Based on the location of the 15 dekad RE maxima, the starting window of the growing season was determined as dekad 34-01. A starting trigger of \( \text{RE} \geq 55\% \) was applied. In this way all actual starts fall in the same range. Strike and exit were formulated as: \( \text{Strike} = \text{Avg} - 1.0 \times \text{StD} \) and \( \text{Exit} = \text{Avg} - 2.4 \times \text{StD} \). A payout simulation was carried out with the 1982-2010 data series. Figures 8.34 and 8.35 present the average payout by year and by location. The yearly payout shows an upward trend since the mid 1990's, which is related to the downward RE trend in figure 8.33. The average payout for the entire period was 5.51\% with a standard deviation of 1.31\% among the wards.

The insurance was priced by re-insurer. The premium to re-insurer was 13.6\%, most likely due to the upward trend in historic payouts (figure 8.34). This price was considered too high. Reinsurer offered an alternative based on \( \text{Strike} = \text{Avg} - 1.5 \times \text{StD} \), resulting in a burning cost of 1.6\% and a price to reinsurer of 8.2\%. This alternative was accepted by broker and sold. During the 2011/12 growing season the index was monitored and reported. Payout according to the original design would have been 4.9\%. But with the alternative design, payout was only 0.33\%. 

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**Figure 8.34**: Bunda district: simulated historic payout by year.

**Figure 8.35**: Bunda district: simulated historic payout by location.
Farmers were disappointed. Particularly at Namhula the damage was said to be big. It was the only location with a payout, being 8%. This would have been 40% in the original design. A pure risk premium of 14% would have been required to give a full payout at this location. The corresponding gross premium would probably have been in the order of 20-25%. This experience points to the existing incompatibility of expectations: farmers want a high coverage at a low price. This dilemma was particularly exposed because of the observed upward trend in payout that considerably increased the price of the drought insurance.

8.4 Drought insurance for maize and rice farmers in Rwanda

Following the Bunda project, MicroEnsure, commissioned the development of drought insurance for maize and rice growers in Rwanda for the growing season 2012. The number of communities was 31 for maize and 24 for rice. The number of participating farmers was considerable: 1725 maize farmers and 4483 rice farmers.

Figure 8.36 presents the historic RE time series at Kigabiru, a location where both, maize and rice are cultivated. The time series shows high variability, different from the Sahel data and similar to the data for the Bunda district in Tanzania. The average yearly RE cycle (figure 8.37) shows two maxima, pointing to a bimodal rainfall regime. The present insurance design concerns the main growing season from March to July.

![Figure 8.36: RE index time series 1983-2012 at Kigabiru, Rwanda.](image)

![Figure 8.37: Climatic average of the annual RE cycle at Kigabiru, Rwanda. There are two growing seasons, one centred in May-June, one in Dec-Jan.](image)
The historic RE data and the information from the field suggest a wide starting window: dekad 4-16. The actual start is based on a required minimum increase in relative evapotranspiration of RE ≥ 7%. In this way the majority of season starts is taking place in dekad 4 and 5 with possible delays up to dekad 16 (figure 8.38). A single phase growing season was implemented with a length of 10 dekads. The possibility of payout on a failed start was included, with 50% coverage for such event. Strike and exit were set at: Strike=Avg-1.2*StD and Exit=Avg-2.7*StD. In addition a deductible of 20% was applied; only total payouts larger than 20% would be transferred. In this way the burning costs remained low at 4.3%. The distribution of the payout by year and location is presented in figures 8.39 and 8.40.

A corresponding drought insurance covering rice farmers was developed for 24 communities, of which 9 were also included in the Maize insurance scheme. All locations showed similar seasonality as those for maize and the design was identical, resulting in average burning costs of 3.81%. The distribution of historic payouts by year and community is shown in figures 8.41 and 8.42. The temporal distribution of payouts (figures 8.38 and 8.40) suggests that 2005 and 2006 were major drought years in Rwanda. This observation is confirmed by international reports. March 2006, the Red Cross reported in their “Rwanda drought emergency appeal” that 1 million people were affected and 33,000 ton immediate food aid was needed. They also requested assistance for the distribution of 200 ton of maize and bean seed and 300 ton of fertilizer to some 50,000 farming families.

After design, approval and pricing by Swiss Re, the drought insurance was sold to 1725 maize farmers in 6 communities and 4483 rice farmers in 11 communities. The 2012 growing season was monitored. The season had a good start in dekad 4-6, depending on the location. Only rice growers at Gitoki experienced serious drought during dekad 8 and 9, leading to a 40.6% payout at this location.
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Figure 8.39: Rwanda simulation of historic payout to maize farmers.

Figure 8.40: Simulated payout to maize farmers by community.

Figure 8.41: Rwanda simulation of historic payout to rice farmers.

Figure 8.42: Simulated payout to rice farmers by community.
8.5 Drought insurance for contract farmers in Malawi and Mozambique

COIN-Re, from Rotterdam, the Netherlands, is developing a large scale risk sharing facility among tobacco contract farmers in Malawi and Mozambique. This facility does not concern the tobacco produced, but the maize that is grown as a second crop. Maize is important to these farmers for food security and additional income. Aggregator is the tobacco company Universal Corporation. The concept is that Universal provides maize input packages to its contract farmers. The price of the input package is deduced from the payment on product delivery. In case of a once in 5 year drought, the payment for the maize inputs is let off.

The main objective of the initiative is to enable farmers to obtain higher yields by using high quality inputs, in particular seeds and fertilizer. In this way maize yields may increase two or three fold. This will be a major contribution to their prosperity and to food security in the region. As a pilot and demonstration project, a maize index insurance has been designed and a dry run has been performed during the 2012/13 growing season. This involved the following target areas, of which the locations are shown in figure 8.43.

<table>
<thead>
<tr>
<th>Area</th>
<th>Country</th>
<th>Nr. of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kabwafu</td>
<td>Northern Malawi</td>
<td>1117</td>
</tr>
<tr>
<td>KU East</td>
<td>Central Malawi</td>
<td>165</td>
</tr>
<tr>
<td>Tete</td>
<td>Northern Mozambique</td>
<td>238</td>
</tr>
</tbody>
</table>

![Figure 8.43: Location of drought insurance target areas in Malawi and Mozambique, super-imposed on the growing season average RE. Note that the colour scale runs from 75 to 100%.](image-url)
Figure 8.44: Average payout history for 165 locations in KU East, Malawi.

Figure 8.45: Average payout history for 1117 locations in Kabwafu, Malawi.

Figure 8.46: Average payout history for 238 locations in Tete, Mozambique.
Figure 8.47: Time course of the RE index during the period 1982-2012 for a location in the target area KU East in central Malawi.

Figure 8.48: Average yearly cycle in KU East, Malawi.

Figure 8.47, above, shows an example of the historic course of the RE index during the entire period 1982-2012 for a location in KU East, Malawi. The average yearly cycle is presented in figure 8.48, showing a unimodal precipitation regime with a growing season from mid November to April. Analysis of the historic data leads to a growing season starting window of dekad 32-37 and a starting trigger of RE ≥ 65%. Emphasis has been placed on simplicity and regular payout. The growing season is therefore treated as a single phase of 12 dekads. The strike is set at the 20 percentile level and when reached, the cost of the maize inputs package is remitted.

A simulation of the historic payouts results in average burning costs of 20%. The standard deviation between locations is small, about 0.5%. An overview of average yearly payouts in the three target areas is presented in figures 8.44 to 8.46 on the previous page. Payouts in the two areas in Malawi are similar in temporal distribution: most occur after 1990, only few in the 1980’s. The opposite is the case for Tete in Mozambique, showing high payouts before 1996 and few thereafter.

Figure 8.49 presents the growing season difference evapotranspiration (DE) map of Mozambique and Malawi, being the difference between the current season’s RE and the corresponding 30 year average RE. The scale runs from -15 to +15%. Green colours indicate above average, red colours below average water availability and crop performance. The following table provides an overview of the overall insurance results of the 2012/13 maize growing season.
Figure 8.49: Difference evapotranspiration (DE) for growing season 2012/13 (dekad 62-78). Scale runs from -15% (dark red)) to +15% (green, blue). On the left, detailedcroppings of the three target areas are shown. Best growing season conditions occurred in KU-East, mid Malawi.

Figure 8.50: Time course of RE at two locations in KU East, central Malawi, where payout was triggered at the end of the growing season.
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<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Nr of farmers paid</th>
<th>Avrg payout</th>
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<tr>
<td>Malawi</td>
<td>Kabwafu</td>
<td>68</td>
<td>28.57 %</td>
</tr>
<tr>
<td>Malawi</td>
<td>KU East</td>
<td>8</td>
<td>4.85 %</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Tete</td>
<td>302</td>
<td>27.04 %</td>
</tr>
</tbody>
</table>

Figure 8.50 shows the time course of the RE index during the growing season at two locations in KU East, Malawi, where a full payout was triggered during the current growing season (red lines). The 1982-2012 average RE course is shown in black. The graph indicates that payout was triggered because of a weak and irregular onset of the growing season and an early end. This was similar in the other target areas.

8.6 Drought insurance for cotton and sorghum farmers in Kenya

January 2012, PlaNet Guarantee and the Alliance for a Green Revolution in Africa (AGRA) entered into a partnership with the objective to develop crop index insurance based on satellite data in Kenya and to cover 55000 farmers by 2017. Consortium partners are APA Insurance, Jubilee Insurance, Rift Valley Products, Kencall and EARS. The project has developed insurance for cotton and sorghum farmers. The cotton pilot, covering 41 communities, ran in 2012 and 2013. The sorghum project, serving 7 villages east of Mount Kenya, was added in 2013.

8.6.1 Drought insurance for cotton growers in Kerio Valley

The development of a cotton drought index insurance concerned 41 villages in Kerio Valley, a part of the Great Rift Valley. There location is shown in figure 8.50, superimposed on an average map of the growing season (April-June) relative evapotranspiration. Figure 8.52 shows the historic time series of the relative evapotranspiration at Kipnai in Kerio Valley, in terms of humidity more or less representative for the average conditions at the 41 locations. From this time series we may derive the average yearly cycle as shown in figure 8.53, which suggests a bimodal regime.

Figure 8.51: Map of the climatic average of the growing season RE, showing the location of the 41 cotton farming communities in Kerio Valley. Scale: 35-100%.
Figure 8.52: RE historic time series at Kipnai in Kerio Valley, Kenya.

Figure 8.53: RE average yearly cycle at Kipnai, suggesting a bimodal regime.

Figure 8.54: Kerio Valley: historic average payout by year.
8.6.2 Drought insurance for sorghum farmers in Meru County

In 2013 drought insurance was additionally developed for sorghum farmers in Meru County. Their location, east of Mount Kenya, is shown in figure 8.56. The climatic average of the yearly RE cycle is presented in figure 8.57. The growing season start appeared narrowly distributed and was chosen correspondingly: dekad 7-9. The actual start was triggered by the requirement ΔRE≥7%. The growing season length was specified by the insurance partner as 7 dekads, subdivided in a vegetative phase of 3 dekads and a reproductive phase of 4 dekads. A payout on start of season failure was enabled, with 30% coverage. Coverage levels for phase 1 and 2 were 75% and 100% respectively. Pay-outs are calculated using Strike=Avg-1.5*StD, and Exit=Avg-3.0*StD.

A historic pay-out simulation was carried out covering the period 1982-2012. The average payout by year and by village is shown in figure 8.58. The average burning costs are 5.85% with a standard deviation of 1.31%. Years with relatively high pay-out are 1984 (58%), 2000 (48%) and 2012 (26%).
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Figure 8.56: Location of seven villages in Meru County, Kenya, superimposed on a climatic average map of the relative evapotranspiration. Scale: 50-100%. Blue area on the left: Mount Kenya.

Figure 8.57: RE average yearly cycle at 7 villages in Meru County.

Figure 8.58: Results of 1982-2012 burn analysis: average pay-out by year (left) and by location/village (right).
The drought insurance design was priced and sold and ran during the 2013 growing season. A monitoring report was prepared and provided to the insurance partner each dekad. The growing season started at Nduruma in dekad 7, at all other locations in dekad 8. As in the cotton area, the growing season proceeded favourably and there was no pay-out. Nevertheless farmers in Nkarini and Tunyai did complain. Their sorghum crop was said to start wilting in dekad 13 and yields were reported to be low. It was argued that although there was abundant rain in the beginning of the growing period, there was no or insufficient rain for 20 to 30 days thereafter.

We have studied this issue, using both precipitation and relative evapotranspiration data generated by the EWBMS system. The precipitation data are based on Meteosat cloud durations, calibrated by WMO-GTS reporting rain gauges in the region, as discussed in section 2.1. Figure 8.59 and figure 8.60 present in green the course of the precipitation and the relative evapotranspiration during the insurance period (dekad 8-14) and a considerable period thereafter. For comparison the corresponding climatic average (in blue) and the year 2000 (in red) are shown as well; the year 2000 saw the most serious drought in the past 30 years.

![Figure 8.59: Course of the precipitation in 2013 (green), compared with the 32 yr average (blue) and the dry year 2000 (red). Growing season indicated by the dashed block.](image1)

![Figure 8.60: Course of the relative evapotranspiration in 2013 (green), compared with the climatic average (blue) and the worst reference year 2000 (red).](image2)
Figure 8.59 shows that there was more than average rainfall during the insurance period: 270 mm in Nkarini (climatic average: 250 mm) and 330 mm in Tunyai (climatic average: 245 mm). It is clear that rainfall was concentrated in dekad 9-11 and that little rain fell thereafter. But sorghum is a drought resistant crop: “the primary root system, with little branching, grows rapidly in deep soils to 1 to 1.5 m. The secondary system starts several weeks after emergence and extends rapidly up to 2 m” (Doorenbos & Kassam 1979). Soils at Nkarini are deep. If the soil is well ploughed, the crop should be able to make optimum use of the rain fallen and stored.

We have checked the Dekadal Agrometeorological Bulletins of the Kenya Meteorological Department. For Meru, they report as follows:
- Dekad 9: maize and beans at emergence and in fair state.
- Dekad 10: maize and beans in fair state.
- Dekad 11: maize and beans in poor state due to excessive rains.
- Dekad 12: maize and beans in good condition.
- Dekad 13: maize and beans in good condition.
- Dekad 14: maize and beans in fair state

So maize and beans performed well in the vicinity of Meru, even though they are drought sensitive crops, while Sorghum is a drought resistant crop. There is however an indication of a possible other cause of damage: excessive rain. Such cause was also reported for Katumani, in the same province: “maize and beans are in the flowering stages and in poor condition due to excessive rains in the previous dekads”. But maximum rainfall (in dekad 11) was less at Katumani (129 mm) than at Meru (232 mm) and at Nkarini (150 mm, figure 8.58).

September 2013, EARS joined insurance partner PlaNet Guarantee in a visit to the area. In Nkarini the problem was discussed with local farmers and a visit was brought to some fields. Since a few years they cultivate a rather new variety of sorghum “Gadam”. The product is sold to a brewery. Farmers insisted that losses were not due to excessive rainfall. When asking for the rooting depth of the crop, the answer was “3 inches”, i.e. 10 cm. This is far less than the rooting depth cited above: 2 m. A field visit confirmed this impression. But suppose this is an underestimation and rooting depth is 30 cm, than this layer could hold only some 9 cm of water, sufficient for at most 2 dekads of potential evapotranspiration. It was not clear what causes the shallow rooting. Is it a property of the variety or is it due to soil conditions? Nevertheless a general conclusion may be drawn: it is not recommendable to insure a crop or variety that has not proven to be adapted to local soil and climate conditions.

Figure 8.61: Meeting with sorghum farmers at Nkarini.
8.7 **Drought insurance for wheat and maize farmers in Kenya, a different design**

November 2011 EARS was requested by the World Bank Agricultural Risk Management Team (ARMT) and the NGO Financial Sector Deepening in Kenya (FSD) to cooperate in testing the RE-index for wheat grower’s drought insurance in the Narok district in Kenya. This test took place in the framework of FSD’s Index Based Weather Insurance Project, supported by the World Bank and Rockefeller Foundation. The piloting phase ran since 2008. However, in 2011 the rainfall based insurance product gave unsatisfactory results. Therefore the satellite derived RE index approach was piloted during the 2012 growing season.

After developing a first design, a working meeting between the partners and a stakeholder training took place in January 2012 in Nairobi. The design was improved several times on the basis of various issues raised and discussed by the partners. After completing the index development for wheat growers in Narok, a similar design was developed for maize farmers in two Millennium Villages in the Siaya district. The location of all communities is shown in figure 8.61. January 20th the Narok design was finalized and ready for pricing by Swiss Re. There was however a complication. Involved credit institutions, insisted to include a fall back methodology. This implied a simultaneous area-yield inventory on the ground. The highest payout from either method would have to be shared out. This requirement was not acceptable to Swiss Re. Therefore the insurance was finally not retailed. Instead a dry run was carried out.

The final insurance design in this project differed notably from the more current designs. The RE is accumulated during the growing season, thus serving as a yield proxy. Payout is based on a difference yield proxy (DYP), being the difference between the current year’s and the climatic average of the yield proxy. The set-up of the Excel workbook is presented in table 8.2.
Table 8.2: Workbook calculations used in the Narok insurance design.

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<td></td>
<td>• Growing season starting window (dekad n-m)</td>
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<td></td>
<td>• Growing season starting trigger</td>
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<td>• Strike formulation</td>
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<td>• Coverage levels</td>
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<td>• Summary of payout simulation (burn study) results</td>
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<td>• RE historic time series for each location</td>
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<td></td>
<td>• Determination of dekad climatic average RE yearly course</td>
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<td>• Start of season determination on the basis of window and trigger</td>
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<td>y</td>
<td>• Determination of the “yield proxy” by accumulation of the dekad RE values from start to end of season</td>
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<td>p1...p3</td>
<td>• Determination of strike, exit and payout in phase 1...3</td>
</tr>
<tr>
<td>pt</td>
<td>• Determination of total payout by community and year</td>
</tr>
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</table>

Figure 8.63: Historic time course of the RE index at Narok-met.

Figure 8.64: Historic time course of the difference yield proxy in Narok.
Figure 8.63 shows the historic time course of the RE index at the Narok meteorological station. At the other locations the time pattern is similar. What strikes at first sight in these data is that the 2000 growing season failed. The course of the difference yield proxy, derived from the RE data, is shown in figure 8.64. The horizontal zero level represents the climatic average at any moment of the growing season. This index accumulates during the growing season like a crop is accumulating biomass. The maxima/minima represent the above/below average yield at the end of the growing season. 1984, 2000, 2011 and 2009 stand out as the worst years.

Based on information from the field the starting window was chosen as dekad 6-12. The growing season actual start was based on a minimum relative evapotranspiration increase of ΔRE ≥ 7%. In this way all actual starts occurred between dekad 6 and 13. Most starts occurred in dekad 7 or 8. The wheat grown is a short season (100 day) variety and, disregarding the ripening period, a growing season phasing of 3/2/3 dekads was chosen.
Strike and exit are determined location specific on the basis of the difference yield proxy (DYP) using: Strike=Avg-1.5*StD and Exit=Avg-2.4*StD. Payouts are possible after a failed start or at the end of each phase. Phase payout (PO) is calculated on the basis of the difference yield proxy (DY) of last dekad of that phase using PO=(Strike-DYP)/(Strike-Exit). Coverage levels where set at 50% on failed start and 50, 75 and 100% for the 3 growth phases. As a possible alternative, also an 8 dekad, single phase design was prepared.

The results of the historic payout simulations are shown in figure 8.65 for the 3-phase and in figure 8.66 for the single phase design. In both designs the same three years come out with large payouts: 1984, 2000 and 2011. The burning costs in key drought years and for the entire period may be summarized as follows:

<table>
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<tr>
<th>Year</th>
<th>3 Phase</th>
<th>Single phase</th>
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<tbody>
<tr>
<td>1984</td>
<td>81.1%</td>
<td>92.4%</td>
</tr>
<tr>
<td>1986</td>
<td>25.7%</td>
<td>4.9%</td>
</tr>
<tr>
<td>2000</td>
<td>81.4%</td>
<td>74.3%</td>
</tr>
<tr>
<td>2008</td>
<td>9.8%</td>
<td>4.6%</td>
</tr>
<tr>
<td>2009</td>
<td>9.2%</td>
<td>17.7%</td>
</tr>
<tr>
<td>2011</td>
<td>48.8%</td>
<td>74.4%</td>
</tr>
<tr>
<td>1983-2011</td>
<td>10.2%</td>
<td>10.2%</td>
</tr>
</tbody>
</table>

A local wheat farmer confirmed these results and referred to 2011 as “horrible” and 2000 as “very bad”. In 2009, he said, only the west part was bad. May 2011 newspaper “The Star” reported: “Wheat farmers in Narok have incurred losses following massive crop failure due to prolonged drought (...) farmers urged the government to waive the loans (...) which amount to KSh 525 million (...) more than 100.000 ha have been lost to drought”. In addition CDP Kenya writes: “In the last 5 year Narok had three seasons of crop failure: 2008, 2009 and 2011” (cdpkenya.wordpress.com). This is consistent with the yield proxy in figure 8.63 and with the payouts in above table. The year 2008/9 stands out less clearly in the payouts, but this is also because first losses are not paid for. Finally, the FAO study “Analysis of Climate Change and Variability Risks in the Smallholder Sector, case studies of the Laikipia and Narok Districts (2010)” mentions 1983/4, 1999/2000, 2007/8, as years of widespread drought. On the basis of the previous evidence it is concluded that the RE data performed well as a drought and crop loss index in Narok and would give correct payouts in major drought years.

The insurance design for the two Millennium Villages Shauri and Ramula in Siaya district was very similar except for some of the settings. Because this concerned Maize, the 3-phase structure was changed to 5/2/5 dekads, while also here a single 12 dekad phase alternative was developed. The strike was set at a somewhat different level: Strike=Avg-1.2*StD. The course of the difference yield proxy, as based on the RE index, is shown in figure 8.66. The corresponding payout history is presented in figures 8.67 and 8.68 for the 3 phases and single phase design, respectively. The difference yield patterns for Siaya show similarities with those of Narok (figure 8.63). Corresponding years of major agricultural drought are 1984, 2000, 2008 and 2011. It should be noted, however, that the intensity of the drought anomalies at Siaya is only half those at Narok. Farmers at Ramula said not to remember any drought years, which would be in line with the single phase payout history (figure 8.68), in which the last payout at Ramula occurs in 1984.
Figure 8.67: Siaya difference yield proxy for the years 1983-2011.

Figure 8.68: Siaya payout history for a 5-2-5 dekad design.

Figure 8.69: Siaya payout history for a single phase 12 dekad design.
The Narok single phase design was chosen for the 2012 growing season dry run, as it was considered to correspond best with the available information. Figure 8.70 shows the climatic average of the yearly RE course, while figure 8.71 presents the actual RE values measured during 2012. Figure 8.72 shows the resulting difference yield proxy during the growing season. The starting window is dekad 6-12, the starting criterion: ΔRE ≥ 7%. 4 locations start immediately in dekad 6, only the location Narok-met starts 1 dekad later. During dekad 8 and 9 there is a dry episode, causing a dip in the DY proxy. However the season proceeds favourably thereafter. At the end of the growing season, the difference yield proxy is everywhere above average and no payout is triggered.

8.8 Summary of pilot project results and current prospects

In the sections 8.1-6 we have discussed several major, though not all pilot projects carried out during the years 2011-2013. In the present section, a brief overview of results is provided. An important issue is the number of farmers insured. A requirement of the Dutch government, as co-financing organisation, is 20,000 insured farmers at the end of 2012. Table 8.3 summarizes the pilot project results. Some 30 different insurance designs have been developed in 10 different countries and in cooperation with 8 different brokers/partners. The number of locations/communities involved in each design grew from 4 in the first pilot in Burkina Faso, in 2011, to 4985 in the livestock insurance design for Uganda, expected to run early 2014.

The one but last column of the table presents the number of farmers insured. For 2012 this number adds up to 22,900. Thus the Dutch government requirement was met and surpassed by 15%. The number of insured farmers in 2013 up to and including the northern hemisphere growing season was somewhat less: 15,215, but is expected to grow considerably in the upcoming 2013/14 southern hemisphere growing season. The COIN-Re insurance projects in Malawi and Mozambique are considerably scaled up aiming to provide a safety net to 150,000 farmers that are currently not insured. In cooperation with Agriculture Reinsurance Consultants (ARC) from Zurich, livestock insurance is being developed for Uganda. This project is commissioned by Lion Assurance Company of Uganda on behalf of a cluster of 8 local insurers. Start of sales is expected early 2014. The product will be offered to livestock farmers all over Uganda. In addition new initiatives are coming up for sorghum farmers in Botswana, with HRA-Maritime, for cotton farmers in Malawi, with Pro-Africa and UNDP and possibly for frost damage insurance in tea with Syngenta Foundation. The outlook for further deployment of FESA Micro-insurance can be considered auspicious.
Figure 8.70: Climatic average yearly course of the RE index at 5 locations in Narok.

Figure 8.71: Course of the RE index during 2012 at 5 locations in Narok.

Figure 8.72: Course of the difference yield proxy during 2012 at 5 locations in Narok. Strike for these locations is between -57 and -71. Therefore no payout.
Table 8.3: Overview of FESA pilot project designs and results.

<table>
<thead>
<tr>
<th>Year</th>
<th>Partner</th>
<th>Country</th>
<th>Area</th>
<th>Crop</th>
<th>Peril</th>
<th>Nr of loc’s</th>
<th>Starting window</th>
<th>Start criterion</th>
<th>Failed start</th>
<th>Season phasing (dekads)</th>
<th>Coverage</th>
<th>Strike formulation</th>
<th>Exit formulation</th>
<th>Deduc- table</th>
<th>Burning costs (PRP)</th>
<th>Nr of farmers insured</th>
<th>Pilot average payout</th>
</tr>
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<tbody>
<tr>
<td>2011</td>
<td>PG</td>
<td>Burkina</td>
<td>Maize</td>
<td>Maize</td>
<td>D</td>
<td>4</td>
<td>14-21</td>
<td>RE ≥ 65</td>
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<td>1</td>
<td>Avg-1.2*Std</td>
<td>Avg-3.3*Std</td>
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<td>2.50%</td>
<td>15</td>
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<td>Maize</td>
<td>Maize</td>
<td>D</td>
<td>8</td>
<td>12-21</td>
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<td>-5</td>
<td>1</td>
<td>Avg-1.2*Std</td>
<td>Avg-3.3*Std</td>
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<td>8.62%</td>
<td>887</td>
<td>Avg-2.4*Std</td>
<td>5.51%</td>
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<td>Kandara</td>
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<td>2 perc</td>
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<td>2.21%</td>
<td>0.1</td>
<td>3.70%</td>
<td>2.21%</td>
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<td>Kandara</td>
<td>Fr.beans</td>
<td>E</td>
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<td>7</td>
<td>fixed</td>
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<td>4.55%</td>
<td>4.55%</td>
<td>4.55%</td>
<td>4.55%</td>
<td>4.55%</td>
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<table>
<thead>
<tr>
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<th>Bunda</th>
<th>Cotton</th>
<th>D</th>
<th>23</th>
<th>34-37</th>
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<th>-15</th>
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<th>Avg-2.4*Std</th>
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<th>5.51%</th>
<th>5.51%</th>
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<td>Narok</td>
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<td>D</td>
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<td>6-13</td>
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<td>+</td>
<td>5/2/5,8</td>
<td>.5/5/75/1</td>
<td>Avg-0.9*Std</td>
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<td>+</td>
<td>5/2/5,8</td>
<td>.5/5/75/1</td>
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<td>D</td>
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<td>+</td>
<td>10</td>
<td>.5/1</td>
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<td>F</td>
<td>8-18</td>
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<td>4/11</td>
<td>.75/1</td>
<td>Avg-1.5*Std</td>
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<td>C</td>
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<td>+</td>
<td>3/6/3</td>
<td>.3/5/75/1</td>
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<td>20 perc</td>
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<td>20 perc</td>
<td>20%</td>
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<td>F</td>
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<td>.75/1</td>
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<td>0.00%</td>
<td>2039</td>
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<td>ΔRE&gt;5</td>
<td>+</td>
<td>3/4</td>
<td>.3/75/1</td>
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<td>Avg-3.2*Std</td>
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<td>+</td>
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<td>.3/75/1/1</td>
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<td>F</td>
<td>20-21</td>
<td>RE ≥ 65</td>
<td>+</td>
<td>4/3/3</td>
<td>.3/75/1/1</td>
<td>5 perc</td>
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<td>5.78%</td>
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<td>+</td>
<td>4/3/3</td>
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<td>2165</td>
<td>F</td>
<td>20-21</td>
<td>RE ≥ 65</td>
<td>+</td>
<td>4/3/3</td>
<td>.3/75/1/1</td>
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<td>5.20%</td>
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<td>D</td>
<td>680</td>
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<td>16-18</td>
<td>RE ≥ 65</td>
<td>+</td>
<td>5/3/4</td>
<td>.3/75/1/1</td>
<td>5 perc</td>
<td>0 perc</td>
<td>4.89%</td>
<td>10</td>
<td>4.37%</td>
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<td></td>
<td>D</td>
<td>680</td>
<td>F</td>
<td>19-21</td>
<td>RE ≥ 65</td>
<td>+</td>
<td>4/3/2</td>
<td>.3/75/1/1</td>
<td>5 perc</td>
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<td>5.16%</td>
<td>34</td>
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<td>4</td>
<td>C</td>
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<td>+</td>
<td>Various</td>
<td>.3/5/75/1</td>
<td>0.9*Avg</td>
<td>0.8*Avg</td>
<td>10%</td>
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<td>3.95%</td>
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<td>Sorghum</td>
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<tr>
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<td>Maize</td>
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<tr>
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<td>Mozamb.</td>
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D = drought, E = excessive precipitation, C = calculated, F = fixed
FESA Micro-Insurance: Crop insurance reaching every farmer in Africa
MARKET OUTLOOK

LEI Wageningen UR is a research organisation developing economic expertise for government bodies and industry in the field of food, agriculture and the natural environment. This organisation has been requested by FESA partner Ecorys to carry out a study of the “Market outlook for satellite-based RE index insurance in agribusiness”. According to the report of this study (Assendonk 2013) the development of an agricultural insurance market in Africa has so far failed. This failure has recently been addressed by several actors intending to facilitate this development, in particular the World Bank, IFC, EU, IFAD and WFP. In recent years they have extensively explored index based insurance for this purpose.

With a grant from the Bill and Melinda Gates Foundation, IFAD and WFP launched in 2008 the Weather Risk Management Facility (WRMF), which conducts research in weather index insurance and supports corresponding pilots. The World Bank has supported several pilot projects. Through its International Finance Corporation (IFC) the Global Index Insurance Facility (GIIF) was launched in 2009 with the objective to promote the development of sustainable markets for index based weather and catastrophe risk insurance in developing countries. This initiative was financially supported by the EU, ACP, the Netherlands and Japan. Also NGO’s get more and more involved. Nevertheless, the penetration of agricultural micro-insurance in Africa is still very limited. In 2011 the premium volume did amount to 6.6 M$, while the total insurance market in Africa amounts to 68 B$.

The study analyzes 10 index insurance projects in Africa providing coverage against drought. An overview of these projects is presented in table 9.1. The data sources that have been used as drought index are either rainfall or the Meteosat derived RE index. PlaNet Guarantee uses the RE index in West Africa because rainfall data are scarce, while 30 year of RE data are available for any location. Also COIN-Re is fully catering on the advantages of the RE index for developing a large scale approach aiming to insure 150 thousand contract farmers.

In the HARITA project in Ethiopia, additional remote sensing data and statistical modelling techniques were applied in an effort to overcome the problem of lacking rainfall data. In the EADI project, also in Ethiopia, WFP used the data of 26 rainfall stations across the country and a crop water balance model to derive the Ethiopia Agricultural Drought Index (EADI). This index showed a correlation of about 80% with the number of food aid beneficiaries between 1994 and 2004.

In the GAIP in Ghana, five rain gauges were used to insure maize farmers up to 30 km distance. In the World Bank Project in Malawi the maximum distance to a rain gauge was also 30 km. Kilimo Salama, by Syngenta Foundation, in Kenya, uses rain gauges up to an advised maximum distance of 15 km. Syngenta Foundation has also explored the development of horticulture insurance on the basis of the RE index.

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MicroEnsure, in partnership with the Rwanda national Meteorological Service has installed several automatic weather stations. Using rainfall data based on cold cloud durations from the University of Reading, it is tried to interpolate between existing rain gauges and to create a history for new ones. In NW Tanzania reliable rainfall data were lacking and there a cotton insurance pilot was carried out with RE index data from EARS.
Table 9.1: Value chain of recent weather index based insurance schemes in Africa.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Name</th>
<th>Country</th>
<th>Object insured</th>
<th>Index</th>
<th>Insured</th>
<th>Broker</th>
<th>Insurer</th>
<th>Reinsurer</th>
<th>Credit providers</th>
<th>Other partners</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Burkina Faso</td>
<td>Mali, Benin</td>
<td>Maize, cotton</td>
<td>RE</td>
<td>Farmers, MFI’s</td>
<td>PlaNet Guarantee</td>
<td>Allianz Africa</td>
<td>Swiss Re, Cica Re</td>
<td>CVECA, MECAP</td>
<td>EARS</td>
<td>Oxfam, AECF, IFC/GIIF</td>
</tr>
<tr>
<td>2</td>
<td>Senegal</td>
<td></td>
<td>Maize, peanut</td>
<td>Rain</td>
<td>Farmers, MFI’s</td>
<td>PlaNet Guarantee</td>
<td>CNAAS</td>
<td>Swiss Re, Cica Re</td>
<td>SWISS Re, Africa Re</td>
<td>CIRAD</td>
<td>IFC/GIIF</td>
</tr>
<tr>
<td>3</td>
<td>HARITA</td>
<td>Ethiopia</td>
<td>Teff, beans, maize, wheat, barley, sorgho</td>
<td>Rain</td>
<td>Farmers</td>
<td>Oxfam</td>
<td>Africa Insur. Co</td>
<td>Swiss Re</td>
<td>Dedebit Credit and Savings Institution</td>
<td>Oxfam, Relief Soc. of Tigray, IRI,</td>
<td>Rockefeller, found. Swiss Re, WFP</td>
</tr>
<tr>
<td>4</td>
<td>EADI</td>
<td>Ethiopia</td>
<td>Sum providing for emergency food aid</td>
<td>Rain</td>
<td>WFP</td>
<td></td>
<td></td>
<td>AXA</td>
<td>World Bank, Govt Ethiopia, Norway</td>
<td>USAID</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Kilimo Salama</td>
<td>Kenya</td>
<td>Maize, beans, wheat, sorgho, coffee, potato</td>
<td>Rain, RE</td>
<td>Farmers</td>
<td>Syngenta Found.</td>
<td>UAP</td>
<td>Swiss Re</td>
<td></td>
<td>Better Capital, EARS, Cardano, Shell found.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>COIN-Re</td>
<td>Mozambique, Malawi</td>
<td>Maize</td>
<td>RE</td>
<td>Univ. Co. Farmers</td>
<td>COIN-Re</td>
<td></td>
<td></td>
<td>Swiss Re</td>
<td></td>
<td>Opprot. Internat., World Bank</td>
</tr>
<tr>
<td>9</td>
<td>Rwanda</td>
<td></td>
<td>Maize, rice, potato</td>
<td>Rain, RE</td>
<td>Farmers</td>
<td>MicroEnsure</td>
<td>SONARWA, SORAS</td>
<td>Swiss Re</td>
<td>Kwale Comm. Bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Tanzania</td>
<td></td>
<td>Cotton</td>
<td>RE</td>
<td>Farmers</td>
<td>MicroEnsure</td>
<td>Golden Crescent</td>
<td>Swiss Re</td>
<td></td>
<td>Tanzanian Cotton Board, Gatsby Foundation</td>
<td>GIIIF</td>
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</table>
In summary the 10 projects studied have relied on a limited number of rain gauges. Missing data are synthetically reconstructed using either rainfall data at further distance or rainfall data estimated by satellite. The RE data developed in the FESA project cover a history of 32 year, have 3 km spatial resolution and can be provided for any location in Africa.

The study also discusses the participation in the index based insurance schemes. In 2012 Kilomo Salama was market leader with some 73000 farmers insured, followed by HARITA in Ethiopia with 19000 farmers. The RE based maize insurance projects of PlaNet Guarantee in Burkina Faso and Mali rank third with some 15000 insured in 2012. It is noted, however that this project started 2 years later than the first two. The index based projects of PlaNet Guarantee, COIN RE and MicroEnsure all expect to grow to several hundreds of insured farmers. Thus a rapid market uptake is foreseen for both ground and satellite based index products.

LEI has finally studied the rationale for the index choice. To this end a number of actors in the value chain were consulted. The study discerns and discusses a number of issues, on both the supply side and the demand side of the market that may hamper the uptake of an index.

9.1 Supply side issues

The four supply side issues considered are (1) availability of measurements, (2) availability of historic data, (3) cost of measurement and (4) up scaling possibilities.

Availability of measurements

As a measure of availability the insured area per unit measurement is taken. In the case of projects that accept rain gauge data up to 30 km distance, the insured area per unit measurement is $\pi \times 30^2 = 2826$ km$^2$. In the case of Kilimo Salama accepting rain gauges up to 15 km distance, the insured area is 706 km$^2$. For the RE index based projects this area is equal to the size of a satellite pixel: $3 \times 3 = 9$ km$^2$. Thus in terms of availability the RE index performs 78 to 314 times better than any of the rainfall based micro-insurance projects.

Availability of historic data

For index design and pricing long historic time series of relevant data are required. In the rainfall based index insurance projects, pricing was usually done on the basis of long rainfall data series of 30 to 50 years. The location of these pilot projects, however, is chosen because of their proximity to existing weather stations with long time series available. In many areas with a demand for crop insurance such data are not available. The RE index can easily address this demand as 32 years of data are available for any location in Africa on a 3 km grid.

Cost of measurement

Automatic, maintenance free weather stations require an investment of about 5000 euro. Their lifetime is estimated at about 10 year, leading to estimated yearly costs of 500 euro. However, implementing weather stations does not solve the problem of historic data and the “reconstruction” of such data may involve considerable other data volumes and manpower, which also have their costs. The FESA RE index is not offered as pure data, but as a complete insurance index service, including design of the index and monitoring of the index during the growing season. Current pricing of
this service is such that at large scale application, costs per insured go down to some 0.5 euro per farmer. This implies that near every rain gauge there would have to be at least 1000 farmers to be insured and (in view of the depreciation) for a period of at least 10 year, so as to bring the data gathering costs at a similar low level as in the case of the RE index.

Up scaling possibilities

Up scaling of index insurance activities is a prerequisite for the development of a sustainable and mature weather index insurance market. This again and even more raises the question of what data are going to be used. In relation to ground based indices, problems arise with respect to availability, quality and compatibility of existing meteorological data sources. In contrast the satellite based indices are widely available, of the same quality and fully compatible. In particular the Meteosat based FESA Micro-insurance approach can truly reach every farmer in Africa.

9.2 Demand side issues

The LEI study has also looked at demand issues. Two such issues were identified: (1) ease of understanding, and (2) trust and coverage.

Ease of understanding

In the case of any index insurance there is always the problem of “basis risk”. The index does not insure a crop loss, but a weather condition that leads to a crop loss. Therefore index insurance is more difficult to market, as the client should understand the relation of the index to the growth of his crop. For farmers rainfall is an almost every day fact and known to be essential for his crop. Farmers know that crops use water but he cannot see evapotranspiration and he usually does not know how it is measured.

On the other hand, however, African farmers have got used to temperature and rainfall being predicted on the basis of satellite information on television. They also know the sensation of wet surfaces being much cooler than dry surfaces. Therefore the measurement of temperature and evapotranspiration from satellite can be explained at the hand of relative simple, daily live examples. Nevertheless some brokers and insurers find the explanation of the index easier when referring to a weather station that can be touched. They may also prefer locally measured and collected data and a locally designed and renewed index.

Trust and coverage

Trust in the solvency of the insurance company and in the coverage that the company is offering is very important. With respect to claim settlement the verification of the RE index is less easy. As the satellite processing system is unique, there are no independent parties that could independently process and verify the index information. What matters, however, is the reproducibility of the data and this could be verified by an expert visitor.

Another element related to trust is the intrinsic basis risk. From plant physiology and agronomy it is known that evapotranspiration is a measure of crop water use and is closely related to crop growth and yield (Doorenbos & Kassam 1979). In this respect the RE index is closer to crop growth than rainfall, as the destination of the rain is not known. The EARS Meteosat derived climatic data products have been validated on
many occasions, also in this final report. It remains important to continue to
demonstrate their correlation with crop yield, although in Africa this is often
hampered by bad or lacking crop yield statistics.

Another element of trust is the spatial basis risk: to what extent does the index reflect
the crop yield at the farm site? Do farmers trust a rain gauge at 15 to 30 km distance
to be representative for their fields? The RE index, with a resolution of 3 km, has the
advantage of being more site specific than the rain gauge based products.

9.3 Market outlook

The analysis of RE index competitive advantages and disadvantages has been
summarized by LEI in table 9.2 below. Competitive advantages mainly originate
from supply side opportunities. Limited availability of local data impedes large scale
implementation of ground based index insurance in Africa. Scaling up is essential for
controlling costs. Only satellite data can realize this with limited investment and at
low cost. Therefore the Meteosat based RE index can be considered a major
breakthrough towards affordable crop insurance.

Despite these distinct advantages, there remain two demand side issues that will
require due attention during further market development: explanation to farmers and
other stakeholders and building trust in the validity of the index. Demonstrating the
comparative advantages of the RE index and further validation is essential and should
be conducted in several regions of Africa.

LEI considers the strength of FESA micro-insurance service that it provides brokers
and insurers not only with data, but with a bundle of services including satellite data
collection and processing, index development and operational index monitoring. For
segments in the insurance market this is the preferred option. Some insurers may feel
these services to be a part of their own core business. However, they are often lacking
a proper understanding of the satellite remote sensing, meteorological and plant
physiological backgrounds.

The LEI study concludes that the market outlook for satellite RE index based micro-
insurance is positive and can be turned into a sustainable activity. It is clear however
that the demand side issues of understanding and trust require due attention.

<table>
<thead>
<tr>
<th>Table 9.2: Limitations to implementing large scale index based insurance in Africa.</th>
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</thead>
<tbody>
<tr>
<td><strong>Supply side issues</strong></td>
</tr>
<tr>
<td>Availability of measurement</td>
</tr>
<tr>
<td>Historic data availability</td>
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<tr>
<td>Cost of data</td>
</tr>
<tr>
<td>Up scaling possibilities</td>
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<tr>
<td><strong>Demand side issues</strong></td>
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<tr>
<td>Ease of understanding</td>
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<tr>
<td>Trust</td>
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SUMMARY AND CONCLUSIONS

Need for drought micro-insurance

Drought micro-insurance is considered a key to poverty alleviation, economic development and climate adaptation. Traditional crop insurance is expensive and sensitive to adverse selection and fraud, and hence has not been very successful yet. Index insurance is considered a good alternative, but also introduces some new challenges. These are known as intrinsic and spatial basis risk, meaning that the measured index is (a) intrinsically not identical to the risk to be covered and (b) that the place of measurement of the index is not the same as the dwelling place of the insured. Rainfall based index insurance has not been very successful yet because of the limited availability of rainfall stations and the high costs of creating, maintaining and operating a sufficiently dense measuring network. Moreover, for pricing the insurance a long data history is required. This problem cannot be solved by placing new rain gauges.

Potential of satellite data

Satellite derived data are recognized as a possibility to address these issues. Satellites provide a dense grid of measurements, from which the relevant data that correspond to the location of the insured can be selected. Moreover, long time series of satellite observations exist. Such data are uniform and objective and can be low cost as they come from a single source.

The normalized difference vegetation index (NDVI) has been measured from polar orbiting meteorological satellites for a long time. Its accuracy, however, suffers from a highly variable viewing and illumination geometry. Moreover it is rather a measure of vegetation cover and much less a measure of crop biomass. This index gives no direct information on drought stress. This is also true for other reflection indices such as the absorbed photosynthetic active radiation (APAR). The lack of relation to crop yield may introduce high intrinsic basis risk.

Another satellite-based technique is the estimation of rainfall fields. The method is usually of a statistical nature and requires intensive calibration with reliable rain gauge data, which in Africa is insufficiently available. The calibration is usually variable in space and time and has to be repeated frequently. Moreover rainfall data need additional models to estimate run-off and the amount of water actually available to the crop. An additional complication is that rainfall and crop growth are not synchronous. Therefore satellite-derived rainfall data also suffer from considerable basis risk.

Meteosat based approach

This report presents the results of the **FESA Micro-insurance** project, commissioned by the Netherlands Minister of Development Cooperation as a contribution to the UN millennium development goals. The project has developed a new source of climatic data and related methodology for drought and excessive precipitation index insurance. To demonstrate its feasibility, a range of pilot projects has been or is being carried out in some 10 African countries.
With support of EUMETSAT, a 32 year database of hourly visual and thermal infrared Meteosat imagery has been completed. Satellite data reception continues in real time. These satellite data are processed with the Energy and Water Balance Monitoring System (EWBMS) to generate temperature, radiation, evapotranspiration and cloudiness data fields, covering the African continent at 3 km resolution.

**Methodology and validation**

After an introduction to the subject in chapter 1, this report first focuses on the explanation of the scientific backgrounds and processing methodology. Chapter 2 discusses the EWBMS climatic data extraction and energy balance calculations. In chapter 3, the validation of the satellite derived data products is discussed. By means of a water balance exercise for southwest Burkina Faso it is shown that the Meteosat derived water balance (precipitation-evapotranspiration) fits very well the reported discharge, demonstrating the reliability of these data. In addition it is shown that the relative evapotranspiration (RE) is proportional to reported district sorghum yields in Niger.

**Comparison of evapotranspiration and precipitation data**

In chapter 4 the properties of the evapotranspiration data are studied by comparison with rainfall data for a number of locations in Tanzania. These completely independent data are shown to give consistent information on drought. There are differences, however. Precipitation and evapotranspiration represent different phases of the water cycle, with the soil as water buffer in between. By consequence there tends to be a phase shift of several dekads to several months between precipitation and evapotranspiration data. Evapotranspiration, representing crop water use, is more closely related to crop yield than precipitation. It is therefore concluded that the Meteosat derived climatic data are a suitable and reliable basis for developing micro-insurance products that can be used across the African continent.

**Proposed satellite based insurance indices**

The proposed Meteosat-derived insurance indices are:

- Dekad relative evapotranspiration (RE) as an agricultural drought index
- Dekad cold cloud duration (CCD) as an excessive precipitation index

RE is proportional to the level of CO\textsubscript{2} assimilation and crop dry matter production (Doorenbos and Kassam 1979) and is therefore a pre-eminent agricultural drought indicator. As a satellite derived insurance index, it has a low intrinsic and spatial basis risk. Its derivation from Meteosat is based on physics and mathematics. No external data are required, which implies that this insurance index can be applied very easily all over Africa, anytime and anywhere. Since geostationary meteorological satellites span the earth, such drought insurance could even be introduced world wide.

The CCD is a measure of Cumulonimbus dwelling time. As in the tropics almost all rain falls from such very high clouds, the CCD is a suitable index of the total amount of rainfall. Extreme rainfall events show cold cloud durations up to 25\% of a dekad.

The Meteosat derived RE and CCD indices provide a relatively low intrinsic and spatial basis risk. The data are uniform, objective and abundant. They can be produced economically. There is no need for extensive ground measuring networks,
which have to be managed, maintained and (inter)calibrated. Moreover the approach
can be scaled up easily. Larger scales, with a high number of insurance clients, will
not only enable economies of scale, but also allow for better risk spreading and
therefore lower re-insurance costs.

**Elements of drought index insurance design**

In chapter 5 the elements of technical index insurance design are discussed. Given the
current state of the art, a 3-phase contract structure (vegetative, flowering, yield
formation) has been implemented. However, with a relatively short flowering phase,
such structure becomes sensitive to an accurate start of the growing season. For this
reason a dynamic start of the growing season has been developed. A start of season
window is derived from 24 year of historic RE data. The actual start is triggered on
the basis of a required RE minimum level or increase.

In this chapter it is also shown that a pay-out calculation on the basis of yield deficits
is identical to one based on the relative evapotranspiration. Pay-out starts at an RE
strike level, increases linearly and reaches 100% at the RE exit level. Three ways of
setting the strike and exit in a location specific way are introduced: (1) the RE
fraction or agronomic approach, (2) the standard deviation approach and (3) the
percentile approach.

**Comparing RE and precipitation based drought insurance design**

In chapter 6 we compare the performance of evapotranspiration and precipitation
based drought insurance in a burn analysis, pertaining to 21 locations (weather
stations) in Tanzania. This is done in exactly the same way for both data sets, except
that a cap of 50 mm/dekad is applied to the rainfall data set. The drought insurance
design pertains to maize with a growing season of 130 days, divided in three phases
of 5, 3 and 5 dekads, respectively. A dynamic start of the season is applied and the
possibility of pay-out on a failed start is included. In all phases, strike and exit are set
at the 4 and 1 percentile level respectively. A 24 year simulation of growing season
performance and related pay-out is done. Payouts are calculated for every year and
every location. The effect of a change in growing season structure from 3 to 2 and
finally a single phase, as well as the effect of leaving out the failed start option is
studied. Decreasing the opportunities for pay-out in this way also reduces the
“burning costs” and consequently the pure risk premium.

The evapotranspiration and rainfall based yearly pay-outs show similar year to year
variation and are very well correlated ($R^2=0.873$). There is good agreement on the six
worst years. In section 6.3 it is demonstrated that the RE based years of major payout
correspond well with the available information on drought, crop failure and food aid.

**Excessive precipitation insurance design**

High precipitation is brought by very high Cumulonimbus clouds, which may be
recognized on the basis of their very low cloud temperature. The total amount of
rainfall is therefore proportional to the dwelling time of these “cold clouds”. The cold
cloud duration (CCD) derived from Meteosat is therefore a suitable index of
excessive precipitation. The methodology was explored for 4 locations in west
Burkina Faso (chapter 7). CCD data series show that extreme rainfall events are well
discriminated. The long term average of the CCD is 3 to 4 percent. The initial design
was very simple: a full pay-out follows if during any dekad the CCD is higher than 15%. This leads to burning costs 16.4% of the insured sum. The last extreme events occurred in August 2003 and 2007. These findings are confirmed by IFRC and UN-OCHA reports.

Pilot projects

After a technology development phase of two years, a number of pilot projects have been carried out during the period 2011-2013. They were carried out in cooperation with a range of insurance companies and brokers. Insurance designs have been developed in some 10 African countries. Six pilot projects are presented and discussed in chapter 8. The role of EARS in these projects is the technical design of the index insurance, up to approval and pricing by (re)insurer, as well as the monitoring of the index during the growing season and resulting pay-out calculations.

Since 2011 EARS is cooperating with Planet Guarantee (Parish, Dakar) to develop drought insurance for maize and cotton growers in Mali, Burkina Faso and Benin. The first pilot started with only 12 communities. During 2012 and 2013 this grew to 843 and 3732 communities, respectively. Some sixteen thousand farmers were insured. Such a large number of communities, each requiring specific index design parameters, can no longer be handled in MS Excel. Scaling up was enabled by developing additional design tools based on Structured Query Language (SQL) and MS Access. In this way it has become possible to develop insurance at national and regional scale, involving every 3 km grid point of the RE database.

In cooperation with Syngenta Foundation index insurance has been designed for French bean growers in Kandara, Kenya. French beans are produced year around, irrigated by streams running down the Kandara mountain range. The RE is shown to be a proper indicator of flow. There is also a fair relation with reported bean yield. Excessive precipitation insurance based on the cold cloud duration (CCD) was developed as well. The CCD shows a fair relation with river flow and the fraction of bean yield not recovered. The highest CCD, during the first dekad of April 1997, was quite extreme: 25%. The insurance designs were priced by Swiss Re, but finally not sold, as processor Frigoken considered the products too expensive.

Lacking suitable rainfall data, EARS was requested by MicroEnsure to develop an RE based index design for cotton growers in 23 wards of the Bunda district in Tanzania during the 2011/12 growing. The RE time series show at some locations a downward trend, leading to an increase of payouts since the mid 1990’s. Though designed at 5.5% burning costs, the price to reinsurer became for this reason 13.6%. This was considered too high. The reinsurer offered an alternative based on 1.6% burning costs and 8.2% premium, which was sold. The season was fairly dry, but only a single community received a pay-out of 8%. Farmers were disappointed. The observed trend in historic RE and simulated payout exposed, in a pronounced way, the ever existing tension between farmer’s willingness to pay and wish to be paid.

Following the cotton project in Tanzania, MicroEnsure also commissioned the development of drought insurance for maize and rice farmers in Rwanda. A 10 dekad single phase growing season was applied and the possibility of a failed start was included. Burning costs were kept at the 4% level. The historic pay-out simulation indicates 2005 and 2006 to be major drought years. This is confirmed by a Red Cross emergency appeal stating that 1 million people were affected. The two designs were approved and priced by Swiss Re and were subsequently sold to 1725 maize farmers.
and 4483 rice farmers. After the growing season there were no pay-outs except one of 41% at Gitoki, due to a 3 dekad intermediate dry period.

Universal Corporation has requested COIN-Re to develop a large scale risk sharing facility among tobacco contract farmers in Malawi and Mozambique. The facility concerns maize, that is grown as a second crop and which is important for farmer’s income and food security. High quality maize input packages are provided by Universal so as to boost maize production. The cost is deduced from payment on tobacco delivery. In case of a once in six year drought, the cost of the maize inputs package is let off. A test run for 1520 farmers in Kabwafu and KU East (both Malawi) and Tete (Mozambique) was done during the 2012/13 growing season. The insurance settings are simple: a single season of 120 days with a dynamic start. The strike is set at the 20 percentile. The average pay-out was also 20% with 0.5% standard deviation among the farmers.

In Kenya, Planet Guarantee developed a partnership with AGRA, APA, Jubilee and others to develop crop index insurance for cotton and sorghum growers. For cotton the target area is Kerio Valley. Some 700 farmers were insured during 2012 and 2013 at 41 different communities. The pure risk premium was between 5 and 6%. A pay-out occurred only in 2012: 2.9% on average. Similar drought insurance was developed for sorghum growers at 7 villages in Meru County, east of Mount Kenya. During the 2013 season rainfall and relative evapotranspiration were above average and there was no pay-out. But farmers reported crop damage. The matter was investigated on the spot. The preliminary conclusion was that the sorghum variety, in use since a few years, shows insufficient rooting. The lesson learned is that it is not recommendable to insure a crop that has not proven to be suitable for local soil and climate conditions.

Commissioned by FSD Kenya and in cooperation with the World Bank ARMT drought insurance was developed for wheat growers in Narok district, Kenya, on the basis of the RE index in 2012, after failure of a rainfall based index the year before. In addition a corresponding design was developed for maize growers in the millennium villages Shauri and Ramula, in the Siaya district. As a result of extensive discussions with the two stakeholders, the development of this index insurance, though based on the same RE data, followed a different path. RE is accumulated during the growing season, thus serving as a yield proxy. The same is done for all previous years and the average course of the yield proxy is determined. Finally a “difference yield” proxy is determined by subtracting the average from current year’s value. Growing season phasing, starting trigger, strike and exit are determined in the usual way. Following the historic pay-out simulation, three years were identified as the worst: 1984, 2000 and 2011. This appeared in line with several sources on the web. Both a 3 phase and a single phase alternative were investigated. The single phase design was finally considered most appropriate. The design was approved and priced but finally not sold. Credit institutions involved in the project demanded a back up crop damage assessment, which was refused by reinsurer Swiss Re. Therefore the project was completed with a growing season “dry run”. Notwithstanding a 2 dekad dry period, the season proceeded favourably and no pay-out was triggered.

Overall results and prospects

The requirement of the Dutch government to financially support this project was to reach 20,000 insured farmers at the end of 2012. The realized number is 22,900. During the piloting phase of the project some 30 different insurance designs have
been developed in 10 different African countries and in cooperation with 8 different insurance partners. Project size, in terms of the number of communities for which the insurance is developed, grew from 4 to 3732 in West Africa and 4895 in the livestock insurance currently being developed for Uganda. This is a national scale insurance project in cooperation with a consortium of 8 local insurers. The number of farmers served may grow to several hundred thousand. Also in West Africa the cooperation with PlaNet Guarantee is expected to expand and the number of farmers insured is planned to grow to 70 thousand in 2015 and to more than 200 thousand in the years thereafter. Large numbers of insured farmers may already be reached in 2014 where the project with COIN-Re is aiming to cover 150,000 famers in Malawi and Mozambique that are currently not insured.

**Market outlook**

LEI Wageningen UR, an organisation of economic expertise in the agricultural domain, has carried out a study of the market outlook for crop insurance based on the satellite derived RE index. The study analyzes 10 index insurance projects in Africa providing coverage against drought. 4 Supply side issues and 2 demand side issues are identified. On the supply side of the market these issues are: (1) availability/density of measurement, (2) historic data availability, (3) the cost the data and (4) the possibilities of scaling up. On the demand side they are (5) the ease of understanding the data and (6) trust.

Based on these issues the large scale implementation of index insurance based on either ground measured rainfall data or satellite derived RE data are studied and discussed. The conclusion of this study is that rainfall based insurance is very much limited on the supply side (issues 1-4), while RE is not. On the demand side, rainfall based indices have the advantage of being better understood and trusted by farmers and stakeholders. Here the Meteosat derived RE index may experience some limitations in terms of understanding and trust. These may be addressed by providing training and brochures explaining the index to farmers and stakeholders, as well as by getting media attention for the system. In the sequel of this development it is important to give due attention to these issues.

**Conclusions**

The *FESA Micro-Insurance* project has amply fulfilled its ambition. A satellite based drought and excessive precipitation insurance system has been developed, and has been validated and tested in a large number of pilot projects. A condensed overview is provided in table 8.3 on page 101. The target of twenty thousand farmers being insured at the end of 2012 has been met and was surpassed by fifteen percent. The number of farmers insured is expected to grow to over hundred thousand in projects to be carried out in 2014 in Mali, Burkina Faso, Benin, Malawi, Mozambique, Botswana and Uganda. In the following 5 years this number is expected to grow to half a million. Note that in 2011 the African market for agricultural insurance was virtually none existing and served only some hundred thousand farmers.

It is concluded that the Meteosat derived relative evapotranspiration (RE) and cold cloud duration (CCD) indices provide an excellent alternative for a precipitation based approach. The data are uniform, objective, validated and abundant. They are shown to perform as good as, or even better than precipitation. As an insurance index they have lower intrinsic and spatial basis risk and are therefore expected to give more accurate payouts. They allow for easy scaling up, while keeping costs down.
Because of their high spatial resolution and coverage they do indeed bring affordable and reliable drought micro-insurance to every farmer in Africa.

But the Meteosat derived indices are new. It remains necessary to build trust among farmers and other stakeholders. Local implementation of complementary drought monitoring and yield forecasting services, and publication of the related information through a variety of media, may support habituation to the data. Strategic cooperation with local insurance companies, banks and agricultural input providers could help to package the insurance product in a logical and attractive way. In addition training and information courses and materials could be developed in cooperation with NGO’s and extension service providers.

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