VALIDATION OF NDVI-BASED CROP INSURANCE PRODUCT THROUGH FARMERS' DROUGHT RECALL EXERCISES IN ETHIOPIA

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ABSTRACT

Index-based crop insurance whereby indices correlated to losses or perils are used to trigger insurance payouts, can overcome some of the limitations faced by conventional insurance. Information derived from remote sensing are an often-used data source in crop insurance programs. One example of these are time series of Normalized Difference Vegetation Index (NDVI) that allow to assess drought by evaluating if greenness levels lack behind expected levels based on historical data. The Geo-data for Innovative Agricultural Insurance Schemes (GIACIS) project is an NDVI based crop insurance project recently launched in Ethiopia in partnership with domestic and international institutions. The objective of this study was to validate the insurance design using a farmers' drought recall exercise. Crop loss information collected through farmers' interviews was linked to GIACIS-calculated indemnity payouts. Correlation between payout and crop loss was carried out, and an assessment of whether GIACIS and farmers concord about which years ranked as worst was performed. Where possible, explanations about deviations were made based on additional data collected during the interviews.

The study shows that drought is the major cause of yield reduction which had different importance on different grid cells. The analysis result of bad year ranking shows the different performance of grid cells from 0.33 to 1 ranking coefficient. On the other hand the overall correlation(R^2) between farmer-reported crop loss and calculated indemnities was 0.61, whereas the R^2 per grid cell (evaluating all years per cell) and assessment each individual year in all grid cells have showed wide range of values from 0.00 to 0.96 and 0.00 to 0.88 respectively. Even though limitations remained, the evaluation of NDVI based seasonal aggregation period used in GIACIS against the practiced calendars of the two crops considered in the recall better fits to teff. Although it is not significant, the correlation results of crops show different values i.e. 0.37 for teff and 0.47 sorghum. An assessment was made if more recent years showed a better correspondence between reported crop loss and indemnities, which may be expected due to better recall for recent dates. It was found that due to the high amount of crop losses and the corresponding high pay outs, the past group of year (2006-2010) better performed than the second recent past group. With the especial emphasis to 2015 to check whether farmers can best recall the drought history, the result is unlikely and found to be less than other individual years in the past. Analysis was also made to evaluate whether different causes could be the source of deviation between the loss and payout. The correlation between payout and losses due to pest and multiple causes without drought indicated R^2 value of 0 signifying that GIACIS doesn't predict pay outs for losses due to causes other than drought. Drought and multiple cause with the presence of drought were compared through correlation and the result showed the same for the two causes (0.57).

Finally, since drought is the prominent cause of crop yield reduction in the study area and the overall correlation result is promising the existing GIACIS model appears to be effective for crop insurance in the study area. The different study grid cells performed differently, so future insurance design should consider the topographic characteristics of grid cells .Moreover, further validation in the same area or other CPS zones need close collaboration with the local government. As it resolve resource limitations, the government should also handle the validation task, if it is needed at large scale.

Key words: GIACIS, NDVI time series, index insurance, agricultural drought

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CPS	Crop Production System
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
GIACIS	Geodata for Innovative Agricultural Credit Insurance Schemes
HEA	Household Economy Approach and the cost of the diet
NDVI	Normalized Difference Vegetation index
WMO	World Meteorological Organization

1. INTRODUCTION

1.1. Introduction

Droughts as the world's costliest natural disasters cause an average of US$ 6-US$ 8 billion global damages annually and are collectively affecting more human beings as compared to other types of natural hazards (Wilhite, 2000). Although there are different definitions of drought based on social, economic and area contexts, (WMO 2006); Paulo et al., (2006) defined drought as "a natural but temporarily imbalance of water availability, consisting of a persistent lower-than-average precipitation, of uncertain frequency, duration and severity unpredictable or difficult to predict occurrence, resulting in diminished water resources availability, and reduced carrying capacity of the ecosystems." (Drucap et al., 1980; Wilhite & Glantz 1985) reviewed different definitions, which agree that drought is a condition of insufficient moisture caused by a deficient in precipitation over some time period. Different factors contribute to the occurrence of drought. Among them are temperature, wind, relative humidity, timing and characteristics of rains, including distribution of rain days during crop growing seasons, intensity, duration and onset of rain (Mishra & Singh 2010).

Droughts can be classified into meteorological, hydrological, agricultural and socio-economical drought (Wilhite & Glantz 1985). Hydrological drought is caused by rainfall deficits and is associated with reservoirs or lake levels within a basin (Rathore, 2004). As meteorological drought is expressed by lack of precipitation over a region for a period of time, agricultural drought "usually refers to a period with declining soil moisture and consequent crop failure without any reference to surface water resources" (Mishra & Singh 2010).

Drought and other weather related perils are big challenges for the developing world, especially to those who depend on agriculture and lack access to insurance, credit and deposit services in rural areas (Miranda & Farrin 2012). Insurance programs hold potential to protect people against social and financial exclusions whose existing drought coping strategies are failing (Mosley, 2009). Agricultural insurance can have advantages of stabilizing farmers' incomes and protect them from impacts of crop failure; encourage farmers to use agricultural technologies; and it can reduce loan default risk which can help farmers to secure more credit terms (Binswanger, 1986). Despite its advantages, agricultural insurance, particularly multi-peril crop insurance have fundamental problems that have hindered its expansion and caused failure in many developing countries (Miranda, 1991; Hazell et al., 1986).

One insurance approach to provide protection from adverse impacts of weather for communities in developing countries is index based insurance which can serve to calculate indemnity payouts based on realization of an underlying objectively measured variable –relative to a pre-specified threshold (Barrett et al., 2008). So far rainfall is the most widely used in index insurance contract design (Bardsley et al.,1984). Index insurance unlike the conventional insurance indemnifies the insurance policy holder based on the observed value of a biophysical index. For the index to be effective, it needs to have a strong correlation with the insurance variable (Miranda & Farrin 2012). The indemnity is paid whenever the actual value of the index is below or above a predetermined threshold index value (Skees et al., 1997). It is a novel mechanism across the globe for smallholder farmers who depend on agriculture particularly where there is no adequate relief assistance (Alderman & Haque 2007). There is a growing popularity of index based agricultural insurance mainly due to its ease of implementation, safeguard from moral hazard and adverse selection problems and its affordability (Turvey & Mclaurin 2012). Index insurance is less susceptible to moral hazard because of the fact that it uses objective and publicly available data (Hellmuth et al., 2009). While moral hazard is connected with the change in the behavior of the insured in such a way that the likelihood and /or magnitude of a loss are increased that affect the insurer, adverse selection occurs when the insurer fails to have clear information about risk exposure of policy holders that would result in over- or underestimation of the payouts and premiums (Barnett, 2004).

Given many advantages over conventional insurance, index insurance suffers from the drawback known as "basis risk" which is the condition of index insurance not to indemnify the insured based on the actual loss occurred (Doherty & Richter, 2002). Basis risk is the situation that insurance policy holders experience if no insurance is paid out when there is a loss or alternatively insurance is paid out but no effective loss took place (Barnett, 2004). Basis risk can arise from imperfect relationship of the index either with the area averaged loss or individual loss where area average and individual losses are linked to covariate and idiosyncratic risk types respectively (de Leeuw et al., 2014). Basis risk is a common problem in all types of index based insurance, which can be minimized, but it is difficult to avoid totally (Rao, 2010). It remains the most serious obstacle affecting the effectiveness of the index insurance as a general agricultural risk management tool (Miranda & Farrin 2012).

Remote sensing provides up-to-date information at different range of spatial and temporal scales and is playing a crucial role in agricultural drought detection, assessment and management (Hasan & Saiful 2011). Anomalies derived from multi-annual time series of vegetation indices have proven a powerful tool to monitor drought and crop growing conditions (Kogan, 1995; Peters et al., 2002). While several options exist to derive drought related parameters from remote sensing (Petropoulos et al.,2015; Tapiador et al.,2012), one successful and often-applied approach is through the use of spectral information to quantify the photosynthetic activity of the terrestrial surface. In that way, drought anomalies can be identified through comparison of the photosynthetic activity between different years to understand if vegetation green-up is lacking behind normal (Tucker & Choudhury 1987).

Normalized Difference Vegetation Index (NDVI) is among many remote sensing indices which has been widely used for drought monitoring (Rhee et al., 2010). The use of multi-temporal Normalized Difference vegetation Index (NDVI) composites derived from multi-spectral sensors onboard polar-orbiting satellites holds great potential for index-based insurance (Makaudze & Miranda 2010). Dense temporal observations of NDVI data from multiple years allows to estimate anomalies of 'greenness', which can be correlated to crop yields and primary production (Turvey & Mclaurin 2012). Because meteorological information is often sparsely available in time and space in developing countries, while spatially and temporally complete time series exist (>15 years), several index insurance pilots shifted from weather-based to NDVI-based insurance schemes (Chantarat et al., 2009).

Nonetheless, an effective insurance design does not only depend on the choice of a data source, but also on how that data source is used (Brown et al., 2011 ; de Leeuw et al., 2014). In the development of effective index insurance, identification of an index that minimizes the associated basis risk remains one of the challenges and the methodology employed in designing the index has its own impact on the performance of the insurance (Chantarat et al., 2013). Besides coming up with a design that makes ecological sense, the real thrust of an index insurance product is to understand if farmers appreciate the product and agree that the product does what it intends achieving. Hence, if the index insurance scheme aims at mitigating drought impacts, a key question is whether important droughts are effectively translated into larger indemnity payments. Therefore, validation efforts are needed to evaluate if low basis risk can be achieved through the collection and analysis of historical data on drought and their effects. One such approach is through farmer interviews that help to reconstruct seasonal drought histories (Vrieling et al., 2016).

The recent National Insurance Scheme launched to cover Ethiopian small holder farmers against crop loss based on the Geodata for Innovative Agricultural Credit Schemes (GIACIS) project is one of the drought mitigation efforts of the country. The remotely sensed driven scheme aims to secure farmers against investment losses that are at peril due to droughts. The project is being run in partnership with ITC-University of Twente, Kifiya Financial Technology PLC (private), Ethiopia; Agricultural Transformation Agency – ATA (public), Ethiopia and National Meteorology Agency of Ethiopia – NMA (public).

The GIACIS framework uses NDVI as a proxy to monitor agronomic drought in 60 Crop Production System Zones (CPS) including the study zone. The zones are above 800masl and classified based on 16 years (1999 to 2014) of NDVI data and identify relatively homogeneous areas concerning their long term NDVI behavior. The NDVI time series based product was developed by ITC-University of Twente. According to the insurance design, indemnity payouts are analyzed separately for each 1km *1km grid cells, even if the statistical information to determine these payouts take in to account similarly behaving cells. The size of the payout unit is decided owing to varying topography and soils, even within small administrative units such as kebeles, rainfall, itself and/or the effects of rainfall on crops in large areas which can affect the accuracy of the insurance design.

The different efforts made including stratification of the project areas based on homogenous Crop Production System (CPS) zones and deigning the insurance on smaller unit will help to minimize the basis risk. Finally, despite the careful and innovative index design of the GIACIS product, up to present the project has not been validated against drought impacts on the ground, as experienced by farmers. Therefore, the study will validate the insurance design through farmers' drought recall exercise.

1.2. Research objectives

1.2.1. General objective

To evaluate if the GIACIS-approach of translating NDVI time series into indemnity payouts for agricultural drought insurance results in an accurate representation of historic drought events as experienced by farmers.

1.2.2. Specific objectives:

1. To collect and analyze farmer drought recall data for environmentally different locations (grid cells) around North Wollo area, Ethiopia.
2. To evaluate to what extent grid-level seasonally-aggregated GIACIS indemnity series capture drought experienced by farmers.
3. To explain deviations between GIACIS indemnity payouts and farmers' experience based on detailed analysis of interview data and NDVI temporal profiles.

1.3. Research questions

Specific objective (a).

1. According to farmers' experience across North Wollo area, is drought the most yield reducing problem experienced in the past ten years?
2. Can areas be identified where drought has a larger importance on yield reduction?

Specific objective (b)

1. Do the three highest GIACIS indemnity payouts at grid level correspond to the three worst drought years as identified by farmers?
2. What is the relationship between GIACIS indemnity pay outs and farmers' crop loss on grid cell basis?
3. Which grid cell's GIACIS indemnity payout best fits to the farmers' claim?

Specific objective (c)

1. Is the seasonal aggregation period used relevant in view of the local crop calendar of the considered crop in the farmers' responses?
2. Is the relationship between GIACIS indemnity payouts and farmers' experience of drought stronger for specific crops?
3. Can intra-annual NDVI distribution in specific season explain some of the deviations between GIACIS indemnities and farmers' experiences?

1.4. Hypothesis

Specific objective (a) for question:

1. Drought is the major yield-reducing problem experienced by farmers in the North Wollo area.
2. Within the study areas, grid cells can be identified where drought is a more prominent problem, whereas other factors (e.g., flooding, pests) play a larger role in other grid cells.

Specific objective (b) for question:

1. The three highest GIACIS indemnity payouts perfectly match with the three drought bad years identified by farmers.
2. Grid level GIACIS aggregated indemnity payout strongly correlate with crop loss claimed by farmers.
3. Grid cells can be identified which has the best fit for GIACIS indemnity payouts and farmers' claim of crop loss.

Specific objective (c) for question:

1. The seasonal aggregation period used in view of the local crop calendar for specific crop fits with farmers' response of crop calendar.
2. The type of crop in the area determine the relationship between GIACIS indemnity payouts and farmers' experience.
3. Intra-annual NDVI distribution in specific season explain some of the deviations between GIACIS indemnities and farmers' experiences?

2. STUDY AREA AND DATA

2.1. Study Area

The study area encompasses two woredas, Haberu and Woldia, in the northeast part of Amhara Region, Ethiopia. Both of the study woredas are located in the North Wollo zone. The zone in general and the study woredas in particular have past and recent drought history that affected the livelihoods of small holder farmers. Since agriculture is the main economic sector and is highly dependent on rainfall variability and amount, weather governs the lives and wellbeing of rural people of Ethiopia in general and the study areas in particular. According to historical rainfall data assessment the drought in 2015 is the worst to central/eastern Ethiopia in more than 50 years that major food security emergency is expected to persist through much of 2016 (FEWS-NET, 2016). This national drought has also affected the two woredas. Undulating topography and steep slopes are two of the characteristics of them. During 1999 to 2004 about half of the rural households in the country experienced at least one major drought (Agrawala & Fankhauser 2008). The study area is found at latitude of 39° 30' & 40° 0' E and 11° 20' & 12°0"N longitude. The study grid cells found in the two woredas are within 1367m – 2613masl altitude.

The altitude and annual rainfall of the North Wollo zone is 700-4100 masl and 600mm (low altitude) to 1200mm (high altitude) respectively. Temperature ranges from 16°C to 25°C. The area has a single wet and dry season. The wet season is from June to September and the dry season is between October and May (Belay, 2010). The zone is divided into three main agro ecological zones, namely: high altitude (>2500 masl) 31.951%, mid-altitude (1500–2500 masl) 57.493% and low altitude (<1500 masl) 10.556%. Most of the zone is mountainous dominated by steep slopes, which are unsuitable for agriculture. The land use system of the area comprises 24% cultivated land, 4.6% pasture, 0.37% forest, 17.4% shrub land, 47.3% degraded land, and the remaining 6.3% is for other land uses (CSA, 2011). The average rural household land holding size is 0.7ha, which is below 1.01 ha and 0.75ha of the national and regional average respectively. Mixed crop-livestock farming is widely practiced agricultural activity. Major crops grown in the study area include sorghum and teff. Though not on large area, maize and wheat are also grown in the same location. North Wollo has a long history of settled agriculture dominated by cereal based farming systems and is drought prone, which has provoked chronic food insecurity and occasional famines (FAO, 1986). Land preparation starts in January for the April planting of long cycle sorghum and maize crops and short cycle Teff is planted in June and July (HEA, 2007). Figure 1 and Table 1 show location of the study area and seasonal calendar of the zone.

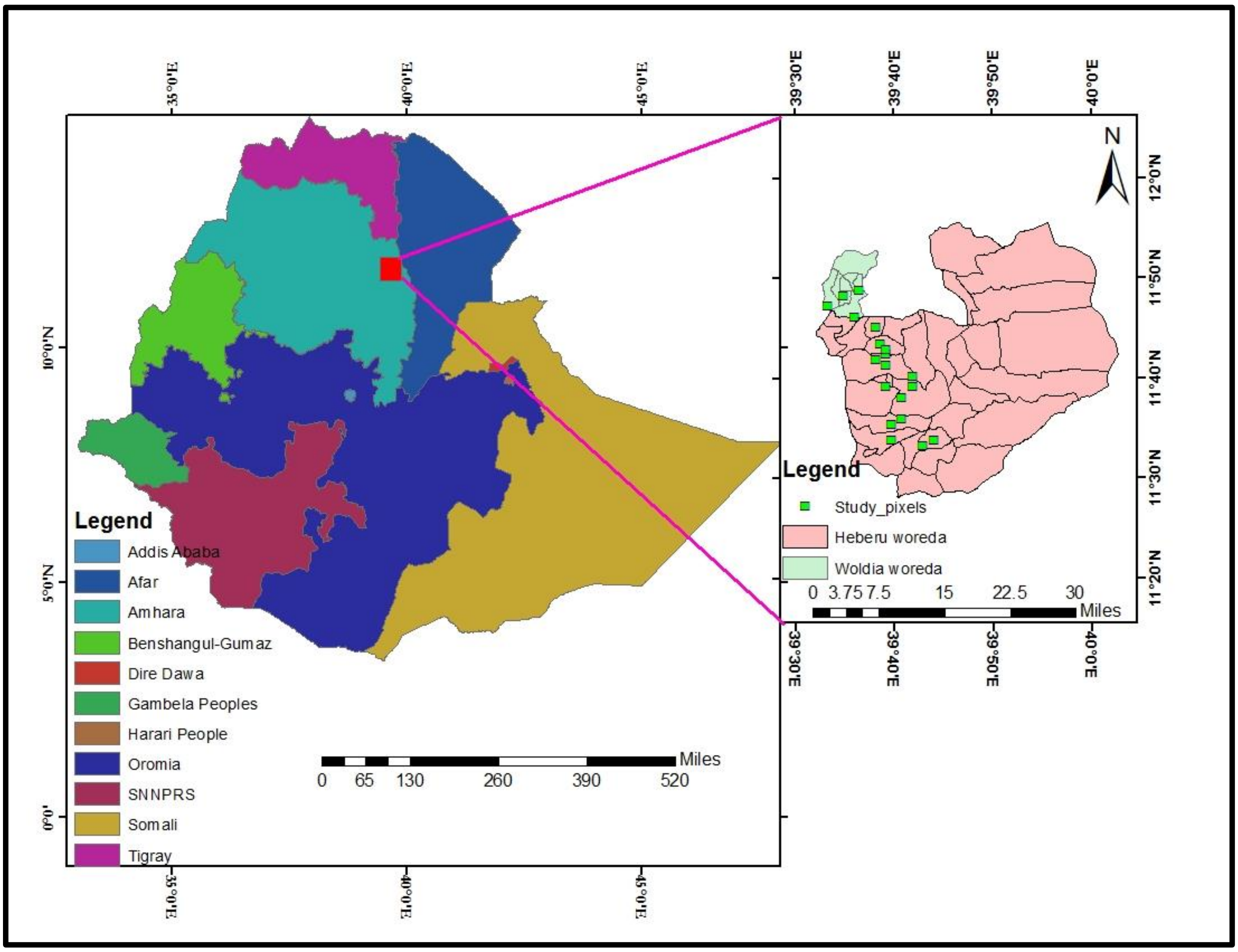

Figure 1: Country map with regional states and study woredas showing grid cells

Table 1: Seasonal Calendar of North Wollo zone (Adapted from Livelihood profile of Amhara Region, Ethiopia August 2007[1])

Seasonal calendar												
	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Rainy season	Bega (dry)		Kiremt (Rain)				Bega					
Legend		Harvesting			Weeding			Planting				
Sorghum												
Maize												
Teff												

2.2. Data

2.2.1. Indemnity time series from GIACIS

Indemnity time series (2006-2015) of the late season were obtained through the GIACIS project. The GIACIS insurance model was designed by University of Twente-ITC and is based on NDVI time series (de

Bie, 2014). For the time period 1998-2014 10-day NDVI composites (S10 product) derived from SPOT-VEGETATION were used, and for recent years Proba-VEGETATION (Proba-V) was employed. These 1x1km composites were obtained through the Flemish Institute for Technological Research (VITO). The data were radio-metrically and atmospherically corrected and residual noise by cloud and haze was filtered using an iterative application of the Savitzky-Golay filter(Chen et al., 2004;Savitzky & Golay 1964).

Within the insurance design, the NDVI series are used for the following purposes: 1) to stratify the area into Crop Production System (CPS) zones that behave similarly through time; 2) to define per CPS zone the start and end of the growing season; and 3) to calculate indemnity payouts based on trigger and exit threshold values that are fixed per zone for each 10-day period. CPS zones are defined as relatively homogenous areas with similar NDVI behavior across 16 years, indicating a similar agro-climatology. According to the data analyzed, Ethiopia has 60 CPS zones. The growing season of each CPS zone has been identified following 10 days revisit time of the satellite used. The satellite provides images per decade in one month. This helped to divide one year (365 days) in to 36, 10 day period. According to the growing season identification logic a ten day period with values above the threshold is growing season whereas a ten day NDVI value below the threshold is considered as non-growing season.

Figure 2: indicates the average NDVI profile of Crop Production System zone 25. According to the graph two peaks of NDVI values occur. The first and minor peak is the reflection of the first rain season which is called belg. The second and major peak represents the main season or kiremt characterized by wide area coverage as compared with belg rain season.

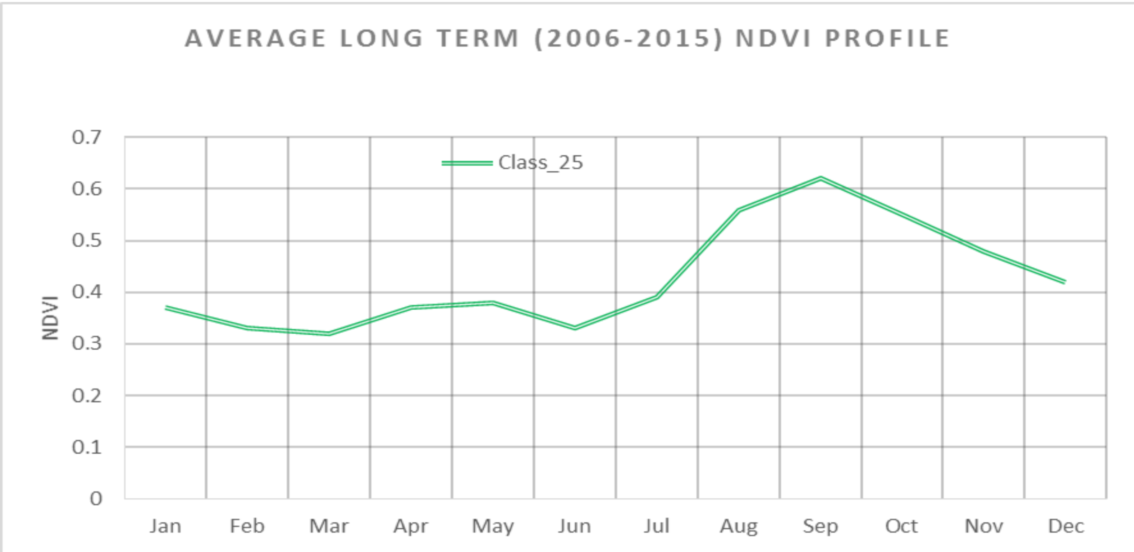

Figure 2: Average long term (2006-2015) NDVI profile of CPS zone 25

Separately for each 10-day period (e.g., 1-10 August) within the growing season, the 16 years of NDVI data for all pixels within each CPS zone are jointly analyzed to determine percentiles. The value for the 15th percentile is used as the trigger value for the insurance, whereas the 5th percentile is the exit value. For any pixel that is part of the CPS zone, the NDVI values for that same dekad are compared against these CPS-based trigger/exit values. If the value is less than the exit value, the indemnity payment for that dekad will be 100%. If the value is larger than the trigger value, the indemnity payment is 0%. If the value is between the trigger and exit value, the indemnity payment will be linearly scaled between 0 and 100%, according to:

Payout= [(Trigger-Actual NDVI)/ (Trigger-Exit)]*100%*sum insured

Percentiles used in the GIACIS project in reference to the NDVI values throughout one year is represented on Fig: 3.

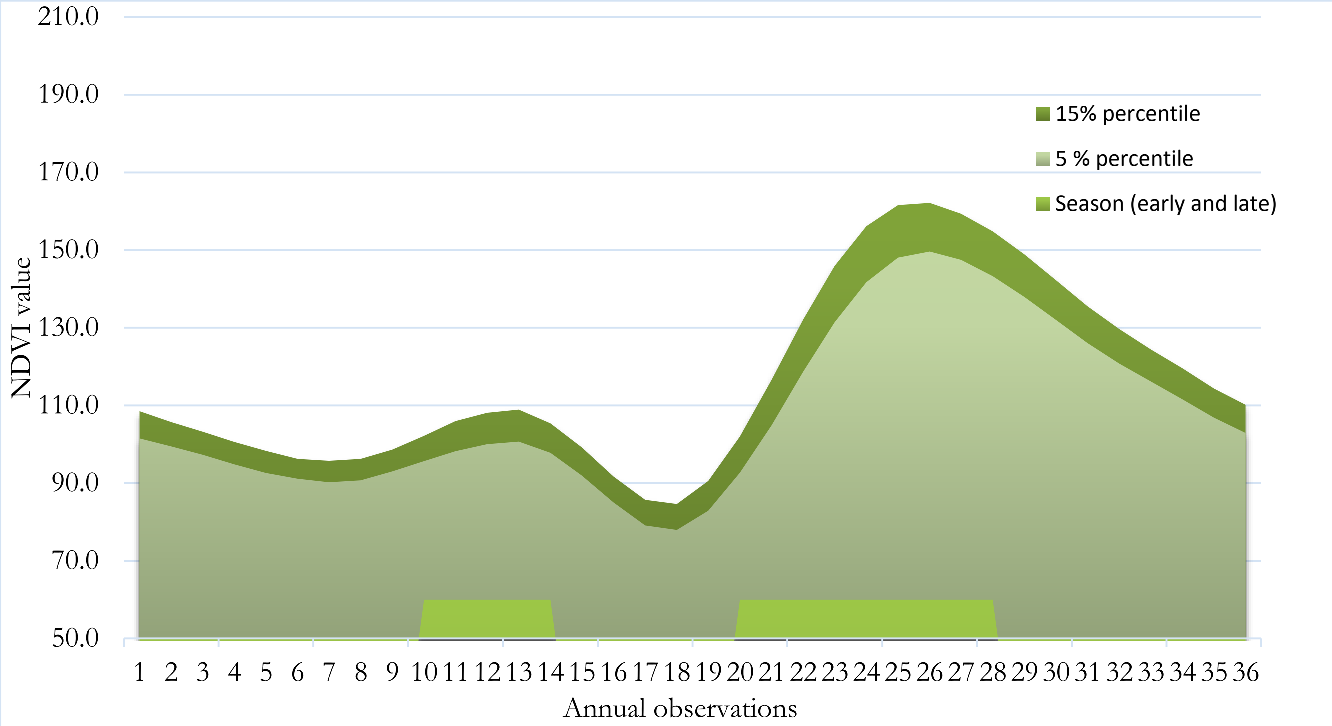

Figure 3: CPS zone -25 GIACIS project percentile graph in reference to the respective NDVI values and annual observation

Note that the precise NDVI values corresponding to the trigger/exit values depend both on the dekad and the CPS-zone. To get per-pixel seasonal indemnities, the calculated 10-day indemnities are averaged in time over the identified growing season. For the selected grid cells of the study area (see also Section 3.2), this resulted in the indemnity payments as shown in Table 2.

Table 2: Pay out result of the GIACIS project for each grid cell during 2006-2015 for CPS zone 25

Grid cell_ID	Payouts (%) for each year										Average grid cell
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
118284	0.00	0	1.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.18**
118759	0.00	0	11.00	0.00	0.00	0.00	0.00	0.00	0.00	8.56	**1.96**
119739	5.56	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.67	**2.12**
120740	1.78	0	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.73**
121765	0.00	0	17.56	0.00	0.00	0.00	0.00	0.00	0.00	23.78	**4.13**
123351	0.00	0	9.22	0.00	0.00	0.00	0.00	0.00	0.00	15.89	**2.51**
124960	28.11	0	20.22	0.00	6.00	21.33	0.00	0.00	0.00	35.11	**11.08**
125498	1.11	0	11.00	0.00	0.00	9.78	0.00	0.00	0.00	12.11	**3.40**
127592	6.67	0	17.44	0.00	0.00	11.67	0.00	0.00	0.00	0.00	**3.58**
126551	36.11	0	38.22	0.00	9.56	13.67	18.44	0.00	0.00	10.56	**12.66**
127597	26.78	0	4.56	0.00	16.56	15.67	26.33	0.00	0.00	0.00	**8.99**
123887	2.89	0	30.67	0.00	0.00	0.00	0.00	0.00	0.00	12.00	**4.56**
131272	9.00	0	24.22	0.00	6.67	0.00	2.00	0.00	0.00	0.00	**4.19**
124422	39.22	0	44.44	0.00	0.00	12.56	0.00	0.00	0.00	28.67	**12.49**
128642	33.67	0	32.56	0.00	4.44	26.33	11.56	0.00	0.00	0.00	**10.86**
130754	55.56	0	45.56	22.22	63.33	13.67	17.56	15.00	0.00	9.11	**24.20**
132842	0.00	0	10.22	0.00	16.22	0.00	2.00	0.00	0.00	0.00	**2.84**
133375	1.11	0	11.22	0.00	38.89	7.11	0.00	1.11	0.00	0.00	**5.94**
132850	30.00	0	0.00	12.22	55.00	24.22	16.44	7.78	0.00	0.00	**14.57**
Average per year	**14.61**	**0.00**	**17.65**	**1.81**	**11.40**	**8.21**	**4.96**	**1.26**	**0.00**	**9.02**	

3. METHODS

3.1. Procedure of the study

Figure 3 Indicates the procedures followed to conduct the study.

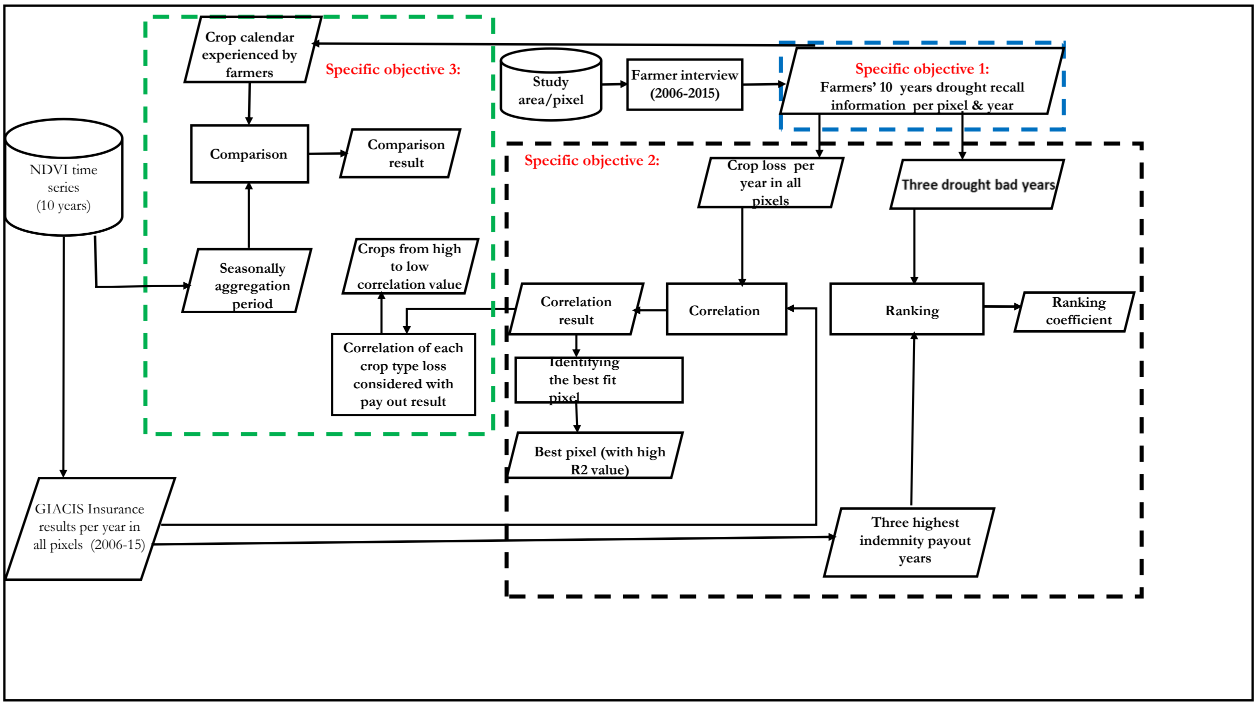

Figure 4: Workflow showing methodologies of the study

3.2. Collection of farmers' drought recall data

Farmer interview data were collected that related to their experience of agricultural drought for the most recent 10 years for which harvesting has taken place (2006-2015). Field data collection was conducted during 7-29 October 2016. A total of 13 kebeles were covered in the two woredas. Major crops grown, annual crop loss, major yield reducing problems, stages of crop development susceptible for damage, crop sowing date, harvesting date and geographical location of farmers' farm land were the key data elements collected from each farmer. Crop loss data is collected by subtracting the production during bad year from production an average year. The same type of unit of measurement (bag of 50kg) was considered by same farmer throughout the 10 years of drought recall in order to know the loss amount each year. Sorghum and teff are the major crop types mentioned by the farmers and consequently considered for the recall. Appendix B shows the data sheet used for data collection.

A total of 20 grid cells of 1km*1km size were initially selected for the study. The intention to limit the sample points to 20 grid cells was because of time limitations. The selection of sampling units was conducted based on a field protocol prepared to validate NDVI based drought assessment in the framework of GIACIS through farmers' interviews (Vrieling et al., 2016). The validation protocol considers accessibility of grid cells, presence of agricultural fields and variability in topography while selecting the study grid cells. Apart from the protocol, variability in payout series was considered in selecting grid cells in order to accommodate the different amount of payout across the study area. All the study grid cells were selected in the same CPS zone 25 that helps to avoid long time series NDVI value difference between them. Digital google image was used to select those grid cells and to prepare map. The map of study grid cells was uploaded on tablet and used for navigation to access the study grid cells.

Following the selection of study grid cells in the two woredas of North Wollo zone, support and permission was sought from Offices of Agricultures of the two study woredas. In the two woredas, deputy head and delegate of the offices were met and briefed about the study. After the brief, experts were assigned to look at the location of each study grid cell on digital Google image and to identify in which kebele they are located. Based on the information each woreda Office of Agriculture had prepared a letter to the kebele development agents and chairmen to let them know about the study and requesting for their cooperation. Both development agents and kebele chairmen participated in selecting the interview farmer and arranging programs with farmers which otherwise would not be possible to conduct the interview. Farmers selection procedure followed GIACIS drought recall protocol (Vrieling et al., 2016). Farmer whose farm land is inside 1km*1km selected grid cell is the primary sources of information about drought. The farmers were selected for the interview using the following criteria:

1. at least 30 years old in order to recall past events related with drought;
2. has farmed in the same location for at least 10 years (to ascertain that recalls relate to the same location);
3. Grows principally one or more of the following crops: Teff, Wheat, Barley, Maize, and Sorghum.

Moreover, interviewed farmers were selected in the way that their agricultural fields are not clustered. The data collection was conducted by the researcher and three assistants. The assistants were local residents who know very well which agricultural field belongs to whom. The farmers wouldn't otherwise be willing to avail themselves for the interview and give the information without them. All of them have experience working with the community in different development activities under the government and with non-governmental organizations. The researcher had worked with assistants for one day and trained them on how to fill the questionnaire and interview the farmers. For the rest of the days the researcher worked as supervisor and navigating to the location of each grid cell to record the longitude and latitude of each agricultural field of farmers. The field assistants and the researcher had tried their best to aware the farmers that the interview is only for study purpose and cannot be linked to a type of crop assessment for aid provision or otherwise.

The responses collected on the survey form were transcribed and organized in a Microsoft Excel workbook with the information from a single farmer summarized in a single row. A total of 152 farmers (19 grid cells times eight farmers) were interviewed. All the interviewed farmers are heads of the household who have better information than other members of the family. The male household heads are responsible to carry out the majority of agricultural activities and make decision on it. Of the total farmers interviewed, only two were female household heads. However, female-headed households are not involved in all labour demanding activities, but are decision makers. They were chosen purposively by kebele chairmen and development agents because of their long year experience in managing agricultural activities and have better information than their sons or daughters in the family. Since women in the study area do not carry out labour demanding agricultural activities such as ploughing, harvesting and weeding activities are done by other paid farmers or by their sons. Alternatively, female headed households contract out their agricultural land and share the agricultural products. In both cases few female household heads have agriculture related information including drought. Farmers in the study area grow different types of crops both for subsistence and commercial purposes, of which sorghum and teff are the two major crops that almost all farmers grow. In addition all farmers inclined to consider only the two crop types for drought recall purpose. From the total interviewed farmer 76% used teff as recall crop and 24 % sorghum. Farmers were free to choose among the different crops they grow for their recall exercise related with drought. Figure 4 shows pictures taken during farmer field interview.

Figure 5: Pictures taken during farmer field interview; the left panel shows farmer interview in a teff-field, the right panel shows agricultural field location recording at Haberu woreda

3.3. Linking farmers experiences to GIACIS indemnities

The amount of crop loss due to drought and /or other factors per grid cell in each year was obtained by averaging the reported loss of eight farmers in the same grid cell. Zero values of crop loss are considered while calculating the averages. The relation and comparison between crop loss reported by farmers and payout calculated in each grid cell across the study years can help to evaluate the drought capturing capabilities of the model used in GIACIS project. Ranking is one of the techniques that can be used to examine the relationship between the two. Bad year ranking between verifiable product and the field data both having same information about drought help to study the relationship between the two sources of information (Osgood et al., 2014). Independently, the three years with highest indemnity payments, and the three years with highest farmer reported losses were listed. A ranking coefficient was calculated as the number of years that match between the two lists. When there is complete agreement between the two, the ranking coefficient will be 1 and otherwise it will be between 0 and 1 (given that three years are used here, the possible values are 0, 0.33, 0.67, and 1.

A correlation analysis was performed between values of crop loss per grid cell during 2006-2015 and the corresponding pay-out prepared by the GIACIS project. Accordingly, 190 values of crop loss (10 years times 19 grid cells) were correlated with values of pay out in the same grid cell and year of study that represent the whole study area. Moreover, loss in each of the grid cells was correlated with pay out result by the model across all ten years which can help to view which grid cell has the strongest relationship and which one has the weakest given the same time period and in the same Crop Production System zone. For the two types of correlations, a large R^2 value would imply that the GIACIS model effectively captured the crop losses experienced by farmers. The crop loss of 19 grid cells was correlated with its predicted pay-out for each study year.

3.4. Exploring causes of deviation between GIACIS indemnities and farmers' experiences

Based on the collected field information, several causes that may explain deviation between GIACIS indemnities and farmers' reported experiences were explored. A first exploration was to evaluate if reported crop calendars (sowing/harvesting) dates matched with the temporal integration periods used in the GIACIS model. Reported (average) crop calendars were summarised per grid cell and for the total study area. Acknowledging that the seasonal aggregation period of the GIACIS model covers the time from NDVI green-up to the start of the greenness decay, which does not necessarily match sowing and harvesting dates, the purpose was principally to evaluate if GIACIS was approximately correct in defining the aggregation period. The cropping calendars of the two crops considered in the recall are collected and summarised independently.

A correlation was also performed to evaluate if the indemnity series have closer correspondence with each of the two types of crops. Each of the eight farmers in each grid cell had independently selected the crop type for recall. This implied that within each grid cell there were reports for: 1) only sorghum; 2) only teff and; 3) teff and sorghum. However, the number of teff and sorghum respondents within grid cell were not equal. To examine if one crop type had a stronger relationship with the GIACIS project pay out result, the frequency of crop mentioned by eight farmers with in a grid cell is decisive factor. Since the average crop loss value of each crop type is used to correlate with the pay out, only crop type registered more than once in a grid cell is considered for the evaluation. Non averaged crop loss value would otherwise be very high that could bring big deviation with the averaged pay out. For instance sorghum or teff is not used for the evaluation in a grid cell where it is recorded only once. Instead either teff or sorghum which is recorded seven times was used. In a grid cell where all respondents used teff or sorghum, average value of that crop was used. Hence, crop only with counts of 8 or 2 to 7 was considered in a grid cell. The average value is calculated by dividing the sum of the loss by each crop to the number of counts the crop is recorded in a grid cell. Finally, correlation made between average crop loss value of each crop and aggregate pay-out of the corresponding study grid cells and years that helps to identify which crop type has stronger correlation.

An additional factor that may explain a deviation between recall results and indemnities might be the number of years that farmers can effectively recall. Likely, the recalling of recent events may result in more accurate information than that of events that happened long time ago. In connection the ten year data was divided in two groups from 2006- 2010 and 2011-2015 to evaluate whether crop losses reported for more recent years showed a stronger correlation with indemnities. Two scatter plot graphs were produced using the two groups of data and their R^2 values were compared. An emphasis was also given to the recent national drought that happened in 2015. In connection, the correlation was performed between the average crop losses of 19 grid cells and the corresponding pay-out to evaluate again whether time of recall matters the correlation result.

Along with other data, all farmers in each grid cell mentioned the different yield reducing factors under three categories based on their severity. Each farmer in a single grid cell was asked to list three different factors which remained to be the major causes for his/her crop yield reduction. The data was collected as 1st cause/s, 2nd cause/s and 3rd cause/s of crop loss throughout all grid cells and years of study. Some responded single factor and some coupled causes under the three categories without the fundamental difference between farmers with in a grid cell. Coupled causes are two causes which affected the crop of a farmer in a single year. Moreover farmers in a grid cell mentioned different years in relation to their 1st, 2nd and 3rd causes of yield reduction. Crop losses corresponding to the three levels of causes were also collected. Each cause of yield reduction and their loss values were matched with the appropriate year. Though farmers mentioned a maximum of three causes and the corresponding crop losses, same data was not collected for the remaining seven years. The causes and crop losses by each farmer were summarised to grid cell level under each year of study. A coupled and single causes mentioned by different farmers in a grid cell in the same year were treated separately. On the other hand the same type of cause mentioned by more than one farmer in same grid cell and year was summarised as one cause. Different causes mentioned by farmers with in single grid cell and year were summarised as multiple causes. This enabled to analyse the deviation between the indemnity series and crop loss due to the different causes of yield reduction throughout the study year in all grid cells using the correlation technique. The responses of eight farmers in each grid cell and total study area in general were summarised under the categories of: D; D+PE; PE; PE+FL; D+FL and SDS. Moreover, yield reduction causes are summarised under each year and grid cell.

4. RESULTS AND DISCUSSION

4.1. Farmers' drought recall information

Based on the interview data several information are generated. One of the first-hand information generated is about age of respondents, sex, number of years farming at location by farmers and major crops considered for drought recall. This gives an insight which group of the people/farmers participated at the interview, major crops of the study area and appropriateness of the number of years farmers' farming experience at a given location to recall ten years events. Farmers' drought crop loss information is also analysed where one grid cell has more crop loss than the other. The difference in crop loss was also identified with in grid cell by different farmers growing same crop. The variation in crop production might be due to topographical conditions. It has been indicated that the topography of different agricultural fields in the study area are variable that affects crop yield (Changere and Lal,1997; Simmons et al., 1989; Schepers et al., 2004). The topography determines soil type that again determine the crop production of the field. Slope as one of the topography characteristics has also impact on the crop production. Hazell, (1992) also indicated that the presence of small difference between agricultural fields in ground contours, slope, wind and sun exposure can lead to the different results of crop damage by: unfavorable climatic, pests and disease events. The crop loss information per grid cell and year is the aggregate average value of the two crop types considered in the recall. Table: 3 and 4 refer summarized information and crop loss for the last ten years by each grid cell respectively.

Table 2: 2006-2015 average crop loss per grid cell obtained from farmers' interview

Grid cell ID	Reported crop loss (average per cell)										grid cell average
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
118284	0.00	0.00	5.88	0.00	0.00	0.00	3.38	0.00	0.00	30.75	4.00
118759	6.00	0.00	15.50	0.00	6.75	0.00	0.00	0.00	0.00	24.88	5.31
119739	11.00	0.00	5.50	0.00	5.63	0.00	0.00	0.00	0.00	6.88	2.90
120740	0.00	0.00	9.50	4.63	9.38	3.88	6.25	0.00	0.00	32.88	6.65
121765	5.00	0.00	23.75	0.00	0.00	0.00	0.00	0.00	0.00	21.38	5.01
123351	0.00	0.00	10.50	5.00	0.00	6.25	2.38	0.75	0.00	8.75	3.36
124960	40.00	0.00	18.00	0.00	0.00	20.50	6.50	0.00	0.00	9.63	9.46
125498	5.00	0.00	9.00	0.00	0.00	10.63	6.00	0.00	0.00	40.13	7.08
127592	13.00	0.00	19.63	0.00	0.00	12.88	0.00	0.00	0.00	6.38	5.19
126551	15.00	0.00	39.25	0.00	0.00	15.00	21.50	0.00	0.00	11.00	10.18
127597	36.00	0.00	5.25	0.00	0.00	20.38	15.00	0.00	0.00	24.75	10.14
123887	6.00	0.00	25.88	3.75	2.50	3.75	4.88	2.25	1.25	6.25	5.65
131272	16.00	0.00	0.00	0.00	10.38	0.00	7.25	0.00	0.00	58.50	9.21
124422	50.00	0.00	50.00	0.00	0.00	14.00	0.00	0.00	0.00	21.38	13.54
128642	41.00	0.00	39.63	0.00	8.63	0.00	0.00	0.00	0.00	3.75	9.30
130754	65.00	0.00	42.50	29.13	72.25	22.00	20.88	10.00	3.63	11.25	27.66
132842	0.00	0.00	15.50	0.00	20.00	8.00	11.00	6.25	4.00	9.25	7.40
133375	6.00	0.00	0.00	0.00	35.13	0.00	31.00	0.00	5.75	20.00	9.79
132850	41.00	0.00	0.00	0.00	46.25	0.00	19.88	8.63	0.00	6.88	12.26
Year average	18.74	0.00	17.64	2.24	11.41	7.22	8.20	1.47	0.77	18.66	

Table 3: Summary of information about interview participants and crops considered in the recall

Characteristic	Unit	Quantity
Age of respondents		
• Maximum	No	90
• Minimum	No	31
• Average	No	52.89
Respondents	No	
• Male	No	150
• Female	No	2
No. of years farming at location		
• Maximum	No	55
• Minimum	No	15
• Average	No	23.41
Major crops considered for the recall		
• Teff	%	74
• Sorghum	%	26

The study identified the different yield reducing factors of the study area in general and grid cells in particular. Without the fundamental difference between them, each of the study grid cells showed different results of yield reducing factors for the last ten years experienced by farmers. Hence, the crop loss reported by farmers is attributed to those factors that farmers didn't clearly quantify the amount of loss by each of the factors when multiple causes affected an agricultural field i.e. crop loss due to drought and pest affected the same agricultural field in the same year was difficult to quantify for each. The crop loss reported by farmers was due to several factors, not solely by drought as the GIACIS project model considered it for pay out prediction. All of interview respondents per grid cell mentioned different crop yield reducing factors experienced for the last ten years. The information regarding the causes in each grid cell is summarized in % (farmers' response) which can tell us the contribution of each of them in reducing the crop yield. According to the analysis, drought had the highest (91.67%) contribution at grid cell 127592 in reducing the crop yield for the last ten years. On the other hand grid cell code 119739 is the least affected by drought (33.33% of the farmers' response). The overall analysis show also that drought had the highest contribution for crop loss. According to the study drought contributed 64.39% (of the farmers' response) to loss crop yield. However, the analysis result for each grid cell is inconsistent with amount of crop loss reported. The grid cells identified severely affected by drought were not in the list of crop loss report with high frequency record or high amount of loss. Such mismatch might be linked to effective recall problem or the damage might be by other causes. Table: 5 indicates different crop yield reducing factors and their contribution in the study area for the year 2006-2015. Coupled causes such as D+PE; PE+FL and D+FL are causes which occurred at one time in in same agricultural field. Regarding the occurrence of the coupled cause, D (Drought) + FL (Flooding) can occur in sequence in single plant population (Loreti and Oesterheld, 1996). Different farmers have encountered such incidence and their crop damaged severely.

Table 4: Causes of yield reduction per grid cell across the study period

Grid cell ID	Causes of yield reduction					
	D	D+PE	PE	PE+FL	D+FL	SDS
123351	46.15	15.38	38.46	-	-	-
118284	68.75	-	18.75	12.5	-	-
120740	52.17	4.35	34.78	8.7	-	-
121765	68.75	-	6.25	6.25	18.75	-
131272	62.5	12.5	16.67	8.34	-	-
127592	91.67	8.33	-	-	-	-
130754	83.33	4.17	-	4.17	8.33	-
132842	41.67	33.33	-	16.67	8.33	-
124422	58.33	25	-	-	16.67	-
128642	70.83	25	-	-	4.17	-
124960	62.5	25	4.17	-	-	8.33
125498	83.33	4.17	8.33	-	-	4.17
127597	79.17	4.17	-	-	16.67	-
126551	79.17	16.67	-	-	4.17	-
119739	33.33	20.83	37.5	-	8.34	-
118759	75	8.33	16.67	-	-	-
123887	41.67	8.33	41.67	8.33	-	-
133375	58.33	8.33	29.17	4.17	-	-
132850	66.67	33.33	-	-	-	-
Average	**64.39**	**13.54**	**13.28**	**3.64**	**4.5**	**0.66**

Data was also collected and analysed regarding the stages of crop development affected during the season by different yield reducing factors. Farmers had tried to explain crop damage at different stages. According to the result, one grid cell is affected by one factor at different stages and by different factors with in single stage of crop development. The information is summarised without linking the causes of crop damage with affected crop development stages. Regardless of the cause of damage, flowering is the most affected crop development stage (58.77 % of the responses) followed by vegetative development stage (20% of the responses). Other stages of crop development including SG (during normal sowing/germination time of crop) and MA (during crop maturity/ripening before harvest) have got responses of 15.13 % and 5.26 % respectively. Though the time of crop development stages were not collected and analysed, the information is vital for the insurance design because of its implication on the yield amount. The study by Van Ginkel et al., (1998) revealed that when drought stress is experienced early in the season, during the vegetative phase, late heading and flowering followed by a short grain filling can be associated with higher yield. However, according to the study flowering stage comes before early drought experienced in the area. This is there for an indication to the crop loss due to drought and is the major incidence throughout the study area.

4.2. Relationship between farmers' crop losses and GIACIS indemnities

The relationship between crop loss reported by farmers and payout calculated by the GIACIS project model can help to evaluate the predicting performance of the model. The relationship between those variables can be expressed by the coefficient of determination (R^2) and means of ranking among their values. The ranking was applied between three highest indemnity pay outs and three drought bad years showed by the highest amount of crop loss in each grid cell and year. The ranking resulted that 8 grid cells have perfect relationship i.e. the ranking coefficient is 1, 4 grid cells with 0.33 ranking coefficient and 7 grid cells with ranking coefficient of 0.66. The interpretation logic of the ranking coefficient values according to Osgood et al., (2014) is that 1 means both the predicted and crop loss years captured drought 100% and 0 is an indication for the disagreement between the crop loss years and predicted payout in capturing the drought in particular grid cell. One possible reason for different result of ranking coefficient might be due to the different biophysical characteristics of the grid cells. Biophysical characteristics can determine yield (Changere and Lal,1997; Simmons et al., 1989; Schepers et al., 2004). Though no formal study was conducted, based on field observation it has been checked that slope, soil type and altitude are different between grid cells. The second reason can be associated with land cover. All grid cells are not 100 % covered by crops. Bushes, gullies, settlement and eroded land are also found with in different grid cells with different area coverage. Individual grid cells capture mix of information from different land covers (Osgood et al., 2014) . Hence, as the reflection information of the crop from those land covers differ from grid cells 100% covered by crops, the result of ranking coefficient between grid cells may vary accordingly. The other probable reason to result in low value of ranking coefficient might be also due to farmers' recall problem. Farmers few years of recall might be the cause for the imperfect match. The distribution of the majority of grid cells (42%) having perfect relationship are adjacent to each other where there is no any other grid cell in between with different ranking coefficient value. Of the total study year and grid cells, 14 grid cells had experienced high crop loss and high pay out predicted in 2008. The other years identified as bad year due to crop loss varies grid cells to grid cells. Those years in different grid cells are: 2006, 2010, 2011, 2012 and 2015. On the other hand the bad years as identified from pay-out calculated are: 2006, 2009, 2010, 2011, 2012 and 2015. Hence, ranking coefficient of the aggregate ranking of bad years between GIACIS indemnity series and crop loss is 0.85. The map of study grid cells with their ranking coefficient values and ranking tables of grid cells are showed on Fig: 6 and appendix (A) part of the report respectively. The map of grid cells with their ranking coefficient values can be used to follow up complaints and to conduct further validation. A farmer may not for instance agree with and follow up can be done using the map.

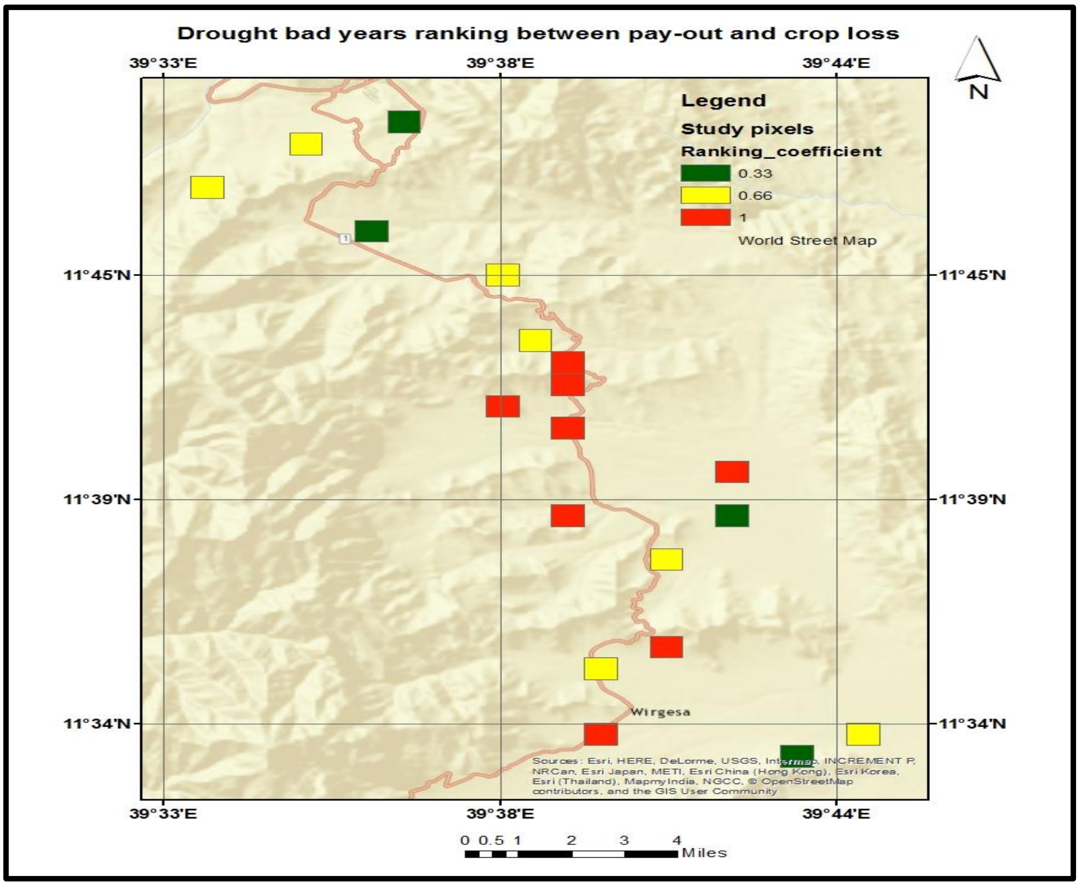

Figure 6: Bad year ranking map based on high amount of crop loss and pay out of grid cells

The relationship between crop losses and pay outs for all grid cells and years combined has a coefficient of determination (R^2) of 0.61 (Figure 7). The majority of crop loss values are higher than the corresponding pay out values. Table: 6 indicates summary of crop loss and pay out of the study area.

Table 5: Descriptive statistics showing farmers' crop loss and pay out

Descriptive Statistics

Characteristic	N	Minimum	Maximum	Mean	Std. Deviation
Loss	190	0.00	72.25	8.63	13.70
Pay out	190	0.00	63.33	6.89	12.33

The correlation result analyses performed for individual years (i.e. to evaluate if the individual year payouts matches the crop loss reporting) gave R^2 values between 0 and 0.88. One reason for no correlation (zero correlation result) between the two variables is due to the existence of complete zero values for loss and pay out under each of the study grid cell and year. The second reason is due to the fact that crop losses claimed by farmers have no the corresponding predicted payouts. In 2007 there was no loss and pay out across all grid cells. Crop loss reported in few grid cells in 2014 had no pay out. Hence, in both cases the correlation is zero. The strange result of the correlation is that of 2015, which is unexpectedly below other previous nine years coefficient of determination and is contrary to Taylor et al., (1988) indicated that farmers recall more recent and/or extreme events than older or moderate ones. The coefficient of determination of the year is 0.032 (Figure 8). The result was possibly partly due to the purposeful responses of farmers. Though the purpose of the study was clearly explained to them before and during the interview time, farmers had mentality about food aid and others due to the recent drought. Almost all of them were mentioning that 2015 drought affected them severely and need support from the government or other organizations. Hence, the result is victim of the concurrent event of drought and the interview. The previous years are free of this unlikely exaggeration knowing that no one provide them aid for losses due to drought or other causes happened some time ago. On the other hand the model by itself might be also other source of the error/low correlation. As the two cases need further investigation, it cannot be concluded that either the model or farmers' response is the source of the error. The highest correlation was obtained in 2010 and is shown on Fig: 9.

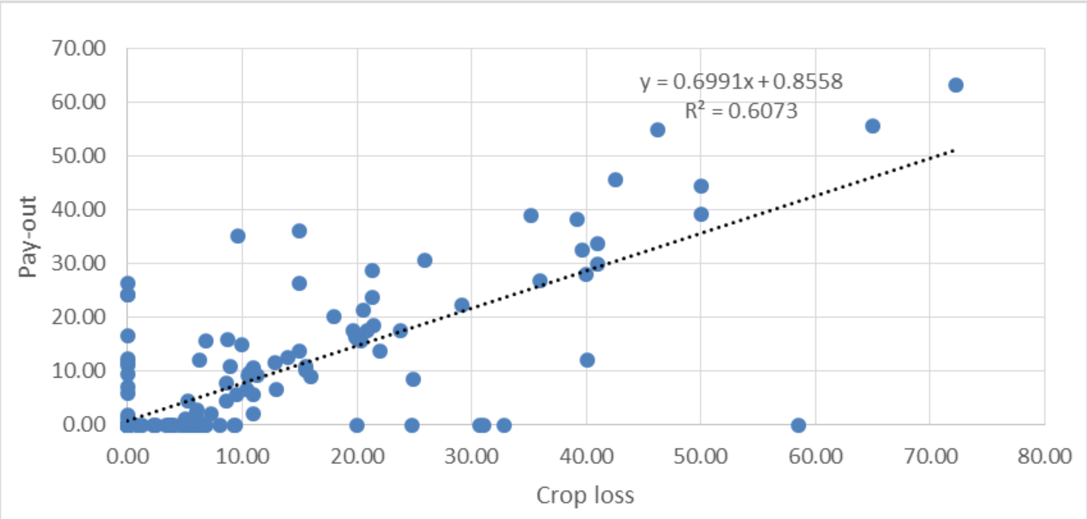

Figure 7: Relationship between grid cells averaged crop loss and GIACIS based indemnity pay outs for the year 2006-2015

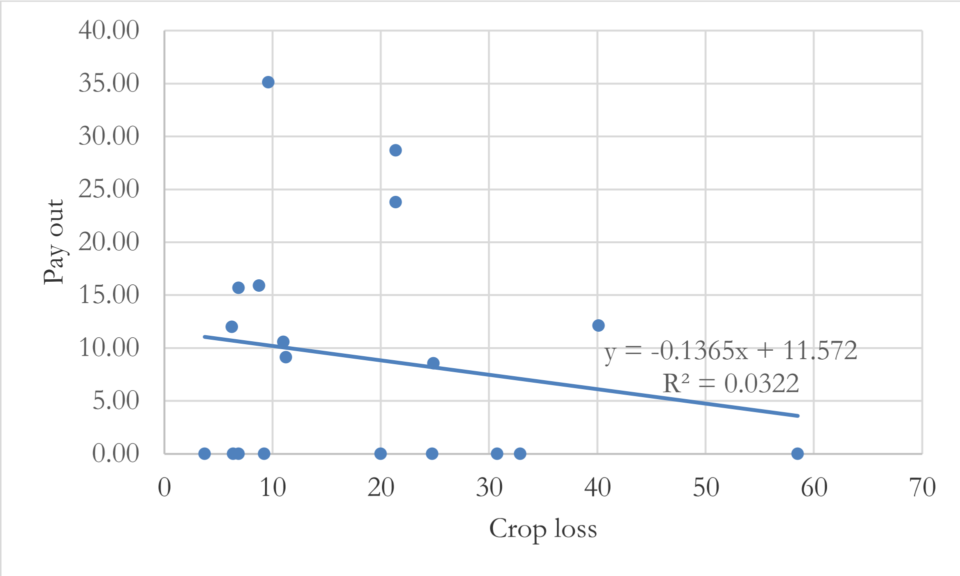

Figure 8: Graph of 2015 pay out and crop loss correlation

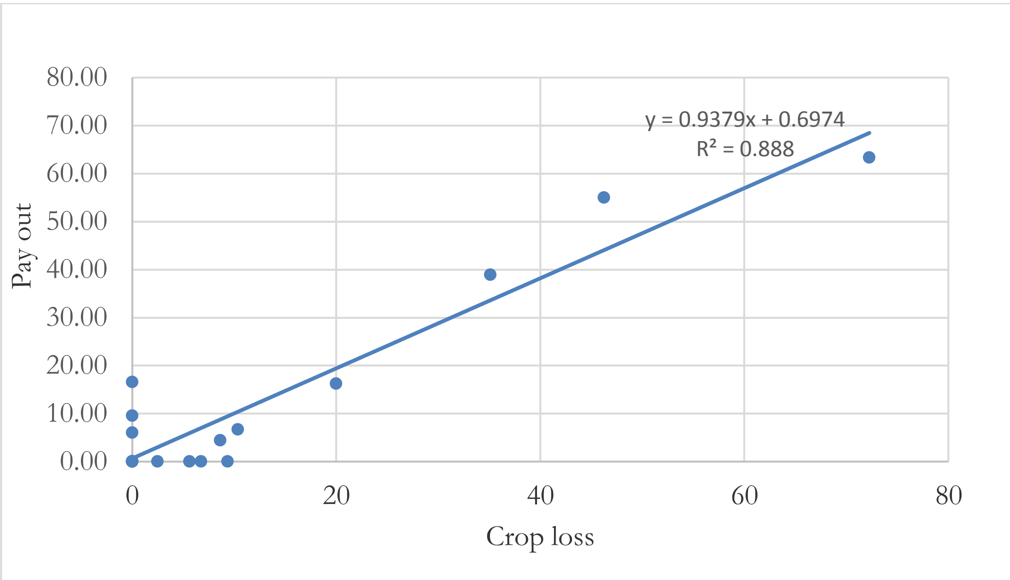

Figure 9: Graph of the strongest correlation between crop loss and pay out of year 2010

According to Taylor et al., (1988), there is better recall capability of farmers in the recent year than the past. Hence, this can be taken as evidence that better correlation will exist between farmers recall in the recent and the model value of same information. However, the result as indicated on Fig: 10 is different. The correlation result (R^2) of 2006 is much higher than 2015. The result would push to undertake further validation for the specific year (2015). The drop of correlation result (0) in 2007 is due to 0 values of the two variables which is an indication for the accurate prediction by the model. With some exceptional cases such as 2007, the graph of the correlation against the study years should show increasing trend i.e. smaller values in the past and higher values in the more recent ones. The result obtained in 2014 is quite different that the losses reported by farmers at four grid cells had no any pay out i.e. the corresponding pay out was zero.

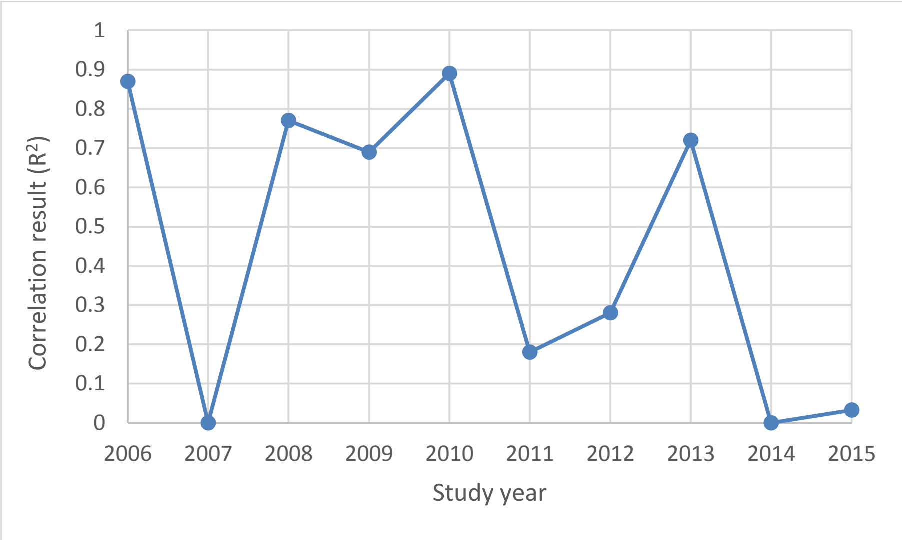

Figure 10: Graphical representation of correlation results (R^2) against the study years

Correlation analyses were also performed per grid cell. Ten years crop loss and pay-out of each grid cell were considered to perform the correlation for 19 grid cells. According to the result, two grid cells (124422 and 130754) have got R2 value of 0.96. Both grid cells have high amount of crop loss and the high amount pay out as compared to the others. On the other hand grid cell 118284 has got the least value of coefficient of determination (0.0047) where the loss is much higher than the corresponding pay out. Of the total nineteen grid cells 12 have above 50% coefficient of determination and the rest are below 50%. Fig: 11 and 12 respectively show correlation results of grid cells with high and least R2 values.

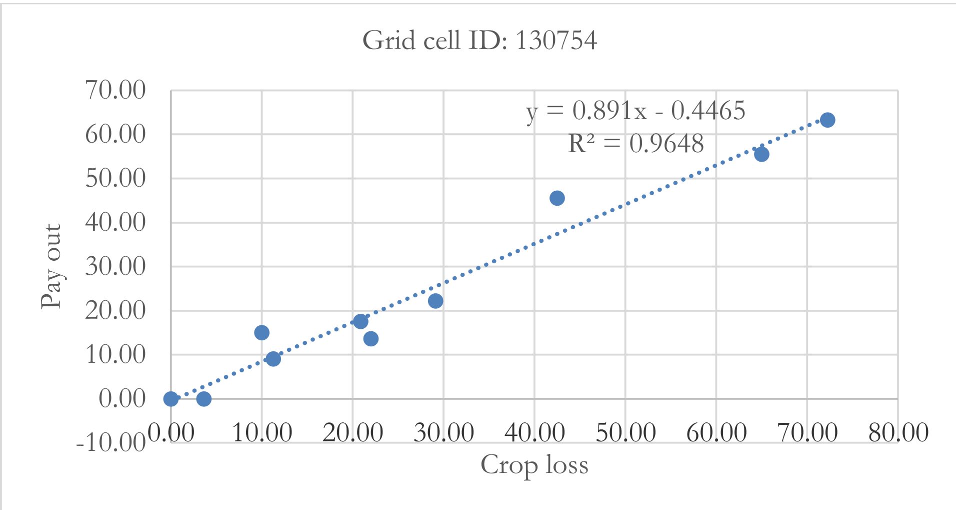

Figure 11: The highest correlation of grid cell 130754 in ten years

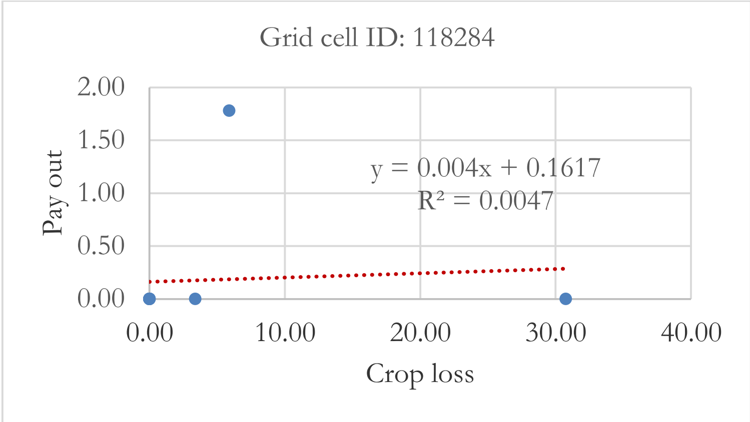

Figure 12: The least correlation value graph of grid cell ID: 118284

Each grid cell showed different performance across ten years. The location of each grid cell with the corresponding correlation result is showed on Fig: 13. This helps to conduct further validation or undertake studies on the specific biophysical characteristics of grid cells with especial emphasis to the grid cells with minimum correlation result.

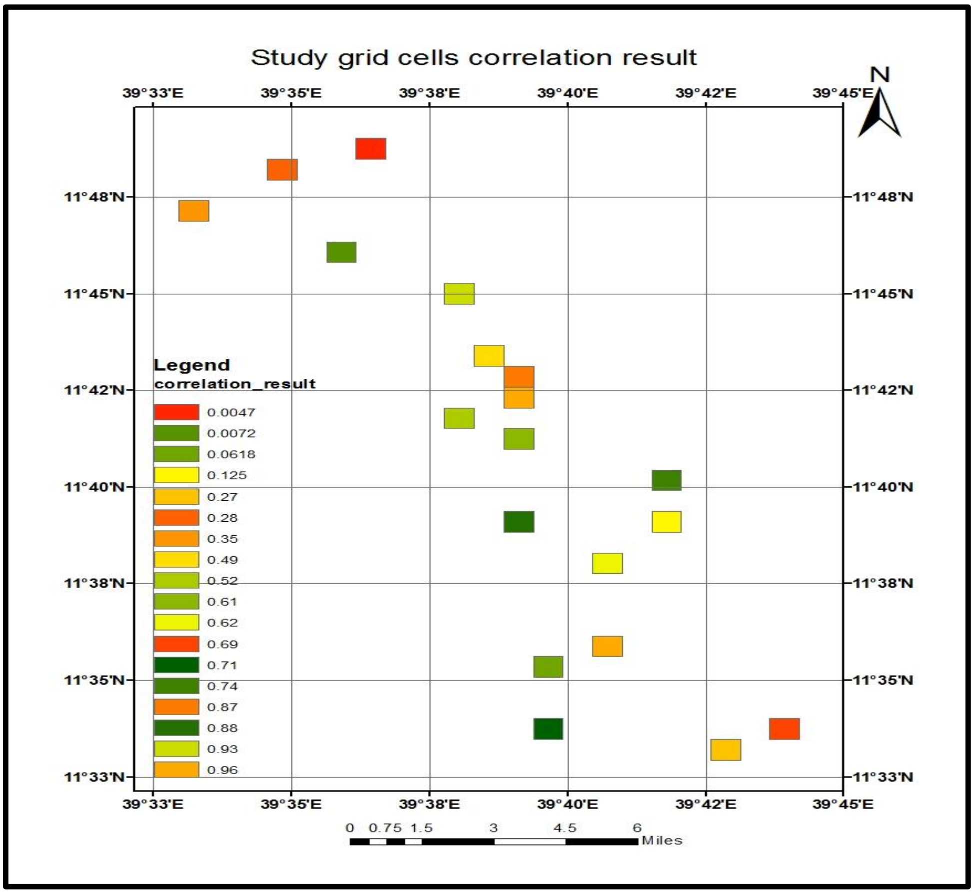

Figure 13: Location map of grid cells with the corresponding correlation result

4.3. Deviation between GIACIS indemnities and farmers' experiences

The previous section showed that reported crop losses do not have a one-to-one relationship with GIACIS indemnities. Different factors might have contributed for this deviation, including for example:

1. Even though other causes were reported that have reduced crop yields, the GIACIS model considers only drought as a factor of crop loss;
2. Sign of exaggeration of loss by farmers was observed due to the fact that food aid is a common drought mitigation strategy in the country in general and the study area in particular.
3. Different biophysical characteristics of grid cells

Two factors namely number of recall years and crop calendar are analysed to see their effect on the model performance. The time factor which was analysed by grouping the data in two groups (2006-2010 and 2011-2015) resulted with different correlation between the crop loss and pay out. The result is strange that the coefficient of determination (R^2) of the correlation under the group of 2006-2010 and 2011-2015 are 0.87 and 0.12 respectively. One of the deviation causes is explored and is associated with the presence of high amount of crop losses and pay out. The idea is strengthened by Osgood et al., 2014 indicating that high correlation is determined by large pay out and loss that result in high correlation. The major crop losses and pay out are recorded in 2006, 2008, and 2010. Fig: 14 indicate scatter plot graph of the two groups of years.

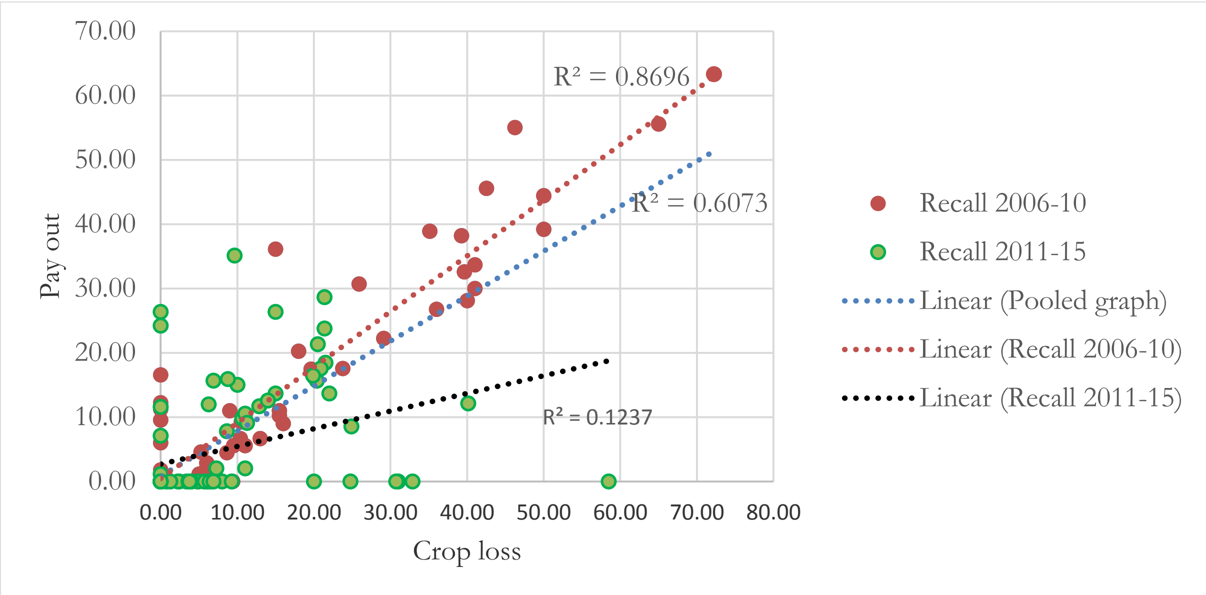

Figure 14: Graph of 2006-2010 and 2011 -2015 showing deviation from over all graph

The second element considered to see the deviation between crop losses and pay out was farmers' practiced crop calendar of the study area. Farmers have different crop calendars for the two types of crops considered in the recall. The sowing and harvesting times of the two crop types are quite different and vary from one grid cell to another. The reported range of sowing and harvesting dates of Teff are from 8 July – 6 August and 11 October – 3 January respectively. Sorghum sowing date is much earlier, which is from 8 April -23 May and its harvesting date is from 10 November – 8 January. However, the data regarding the emergence and ripening stages of the two crops that would enable to evaluate whether the model exactly predicted it or not is not collected. The seasonal aggregation period of the GIACIS project covers dates of the year from1st July to 10th October. Teff sowing and harvesting dates better fit to the GIACIS seasonal window as compared to sorghum. However, the comparison should be done with the same information. The satellite based information regarding crop phenology can be evaluated against the ground phenology. The presence of linkage between satellite derived crop phenology and ground based phenology is studied by (Liang et al., 2011). According to the seasonal aggregation period, NDVI recording starts with the first emergence of the crop to the final day of harvest or ripening stage. Farmers' response regarding the sowing and harvesting dates of the two crops varies even within the grid cell, but the reason for this variability was not investigated. However, the cause might be micro topographic characteristics. Though not studied in detail to answer how much, the presence of gap between the practiced crop calendar and seasonal aggregation period may affect the model result in predicting the pay-outs, and based on the larger deviation this could be stronger for the sorghum crop. However, in this particular study the seasonal aggregation period used in pay out calculation didn't bring any significant difference as tested using correlation for each crop. Other crops with long cycle maturity may be affected by this seasonal aggregation and further study is crucial to evaluate the impact. The study result may also be different for teff and sorghum, if study is to be conducted in the other locations of same zone.

The strength of the correlation between the two crops used in the recall and the aggregate pay out were checked separately in nineteen grid cells throughout all study years. The intention to study the two crops in separate manner was to check whether crops could show deviation because of their different biological nature. As the average values of those crops is used to correlate with the corresponding pay out, crop recorded more than once is considered for the evaluation with in the grid cell i.e. only teff is considered in the grid cell with seven records of teff and one sorghum or vice versa. The number of records (counts) of the two crop types varies with in and among grid cells. In relation teff having two to eight counts is studied in eighteen (18) grid cells. On the other hand sorghum is studied only in nine grid cells. This information tells us that farmers grow more teff than sorghum. The correlation using average losses of each crop resulted in R^2 value of 0.47 and 0.37 for sorghum and teff respectively. As it can be seen the two crop types have no significant difference for their coefficient of determination (R^2) values. Thus, the study result indicate that pay out calculation on crop aggregate basis is accurate that would otherwise require additional resource and skill in designing the insurance for each of the crop. However, the study couldn't address the reason why the correlation of teff is less than sorghum given the aggregation period better captured teff crop calendar and this shall be an issue to incorporate if similar studies are to be carried out in the same zone. Fig: 15 and 16 refer the scatter plots of teff and sorghum respectively.

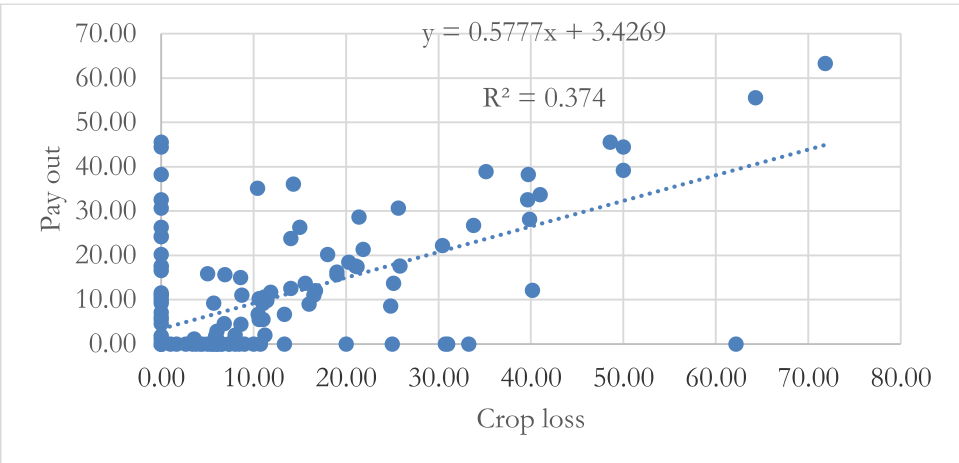

Figure 15: Scatter plot graph between teff loss and the aggregated pay out

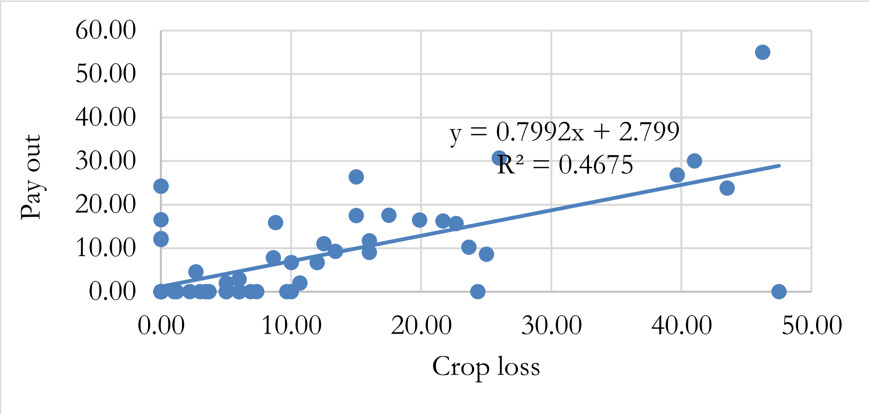

Figure 16: Correlation graph between sorghum loss and the aggregated pay out

Farmers in each grid cell were asked to recall a maximum of three worst years in relation with their crop loss and the corresponding causes of yield reduction. Farmers had mentioned 1st, 2nd and 3rd causes of yield reduction and the corresponding crop loss for the last ten years (2006-2015). However, some farmers were limited to one to two years of crop loss depending on the frequency of the crop loss they faced across ten years. Using the causes and the associated crop loss recall by each farmer in a grid cell for the year 2006 - 2015, only 87 values of crop loss and the associated causes were identified. Of the total, 30 crop losses were due to drought (D), 9 pest (PE), 42 multiple causes including drought, 5 multiple causes without drought and 1 SDS (short drought spell at critical time). Multiple causes with and without drought include: pests, flood, flooding and SDS with different composition. Multiple causes of crop yield reduction may occur after drought. Rosenzweig et al., (2001) indicated that when intense rains occur after drought, soil water absorption capacity can be reduced that can increase potential of flooding thereby creating favourable conditions for fungal infestation of leaf and root in runoff areas. Different causes were coined to multiple causes because of the occurrence of different causes in one year per grid cell as reported by farmers. On the other grid cells single cause of yield reduction reported and summarised as single cause. Thus, whether a single cause is reported by one farmer or eight farmers, only one record (name of the cause) is taken and associated to the crop loss so as to correlate to the pay-out (e.g. only drought by one farmer or drought by eight farmers). Appendix: C indicate summary of causes and the associated crop loss with the corresponding pay-out in each grid cell and year. The symbols on the appendix represents: D (Drought), FL (Flooding), PE (Pest/Diseases) and SDS (Short drought spell at critical time). Coupled causes that had occurred in same years on single farm land are joined with + (plus sign).

According to the analysis result some of the crop losses reported by farmers had no any pay-out. It has been observed that the causes for losses were different from drought. Those causes were PE (Pest/Diseases) and multiple without drought. This is an indication that the insurance design has filtered the crop losses due to causes other than drought and didn't predict the pay-out. Hence, this can be taken as one of the prediction capabilities of the GIACIS project model. Table: 7 and 8 indicate crop losses due to PE and multiple respectively. The study also showed that pest and drought are linked hazards. This finding is strengthened by Rosenzweig et al., (2001) indicated that pest infestation can occur along with the changing climate conditions such as early or late rains, drought and increase in humidity.

Finally, correlation strength (deviation) was tested against the pay outs using three causes of crop loss by rejecting SDS that has only one record. While the correlation results (R^2) of PE and multiple without drought is 0 the results due to drought and multiple causes together drought is resulted 0.57. The study also showed the mismatches between the model predicted pay out and crop loss is due to the causes other than drought. The crop losses reported by farmers due to pest/disease and multiple causes other than drought have got zero pay out. The model has accurately filtered the crop loss due to causes other than drought. This information is consistent with the finding that Normalized Difference Vegetation Index helps to monitor drought(Rhee et al., 2010). The Annex: C and Fig: 17 show summary of causes of yield reduction in all grid cells across all study years and scatter plots using those causes respectively.

Table 6: Pest related crop loss

Grid cell ID	Reference year	Crop loss	Pay out	Causes of crop yield reduction
120740	2009	4.625	0	PE
123351	2009	5	0	PE
118759	2010	6.75	0	PE
119739	2010	5.625	0	PE
120740	2011	3.875	0	PE
123351	2011	6.25	0	PE
125498	2012	6	0	PE
123887	2013	2.25	0	PE
133375	2014	5.75	0	PE

Table 7: Crop loss by multiple causes without drought

Grid cell	Reference year	Crop loss	Pay out	Causes of crop yield reduction
119739	2008	5.5	0	PE+FL
123887	2010	2.5	0	PE;FL+PE
132842	2011	8	0	PE+FL
133375	2012	31	0	PE;PE+FL
130754	2014	3.625	0	PE+FL

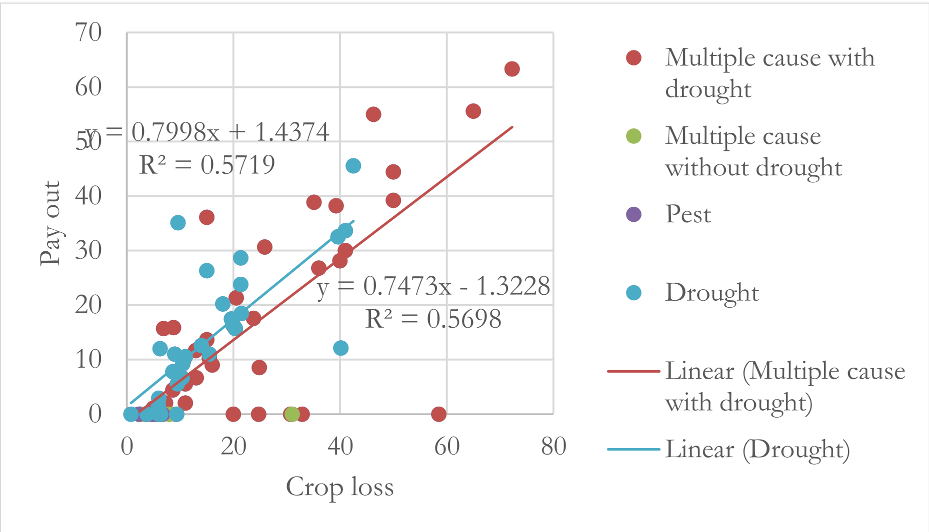

Figure 17: Graph of correlation between pay out and crop loss due to drought, pest multiple causes without drought and multiple causes with drought

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study demonstrated that the crop losses at different grid cells are different even though they are in the same crop Production System (CPS) zone and farmers grew same crop type in same year. Different performance of grid cells and years of study were identified through correlating the crop loss with the corresponding pay out. The variation of the correlation ranges from 0.00 to 0.96 and 0.00 to 0.88 per grid cell and study year respectively. Two grid cells were identified with high performance expressed by their correlation result. The variation was also identified with in the grid cells where eight farmers participated in the recall process. The study confirmed also the difference in the performance between grid cells through applying bad year ranking technique where individual grid cells were studied based on their highest crop loss years and pay out of same years. According to the study, grid cells performed from 0.33 – 1 ranking coefficient values. Effort was also paid to explore whether drought has equal importance across the study areas or not. The study showed that different grid cells were hit at different scales by drought. Moreover, drought is found to be the most yield reducing factor (64% of farmers' response) as compared to pest/disease, flooding and short drought spell at critical time. However, the study didn't come up to conclude about the seasonal aggregation period in view of the practiced crop calendar of the two crop types considered in the recall. While the seasonal aggregation time period covers from the emergence of the crop that NDVI reading could be possible up to the time of ripening, the collected information about practiced crop calendar ranges from the first day of crop sowing until harvesting time. In the situation, it could be possible to see that teff crop calendar is closer than sorghum to the seasonal aggregation period. The study also showed that no significant model performance difference between the two crop types, although pay out calculation is made on aggregate way. It was also checked that the more recent time period model performance was excelled by the previous due to high crop loss and the corresponding payout in the past. Comparison was made by categorizing the study year in to two groups as recent past and past. In the single year evaluation the result of 2015 is unlikely contradicting with the fact that farmers would have best recall of the recent year. Though detail study was not conducted, it was observed that farmers were frequently mentioning aid for the recent past drought and it could have forced them to exaggerate their loss where no pay out is predicted or loss is higher than pay out. On the other hand the study identified that some of the losses reported by farmers across the study areas and years including 2015 are associated with none drought causes that pay out was not calculated as well. Finally, the study could be able to identify that flowering is the most affected crop development stage (59% of farmers' response) in the past ten years.

5.2. Recommendations:

1. Unlike the seasonal aggregation period, the cropping calendars of the two crops hold extended months from their sowing to harvesting. Thus, the cropping calendars of the two crops missed important information about the timing of crop emergence and ripening as seasonal aggregation period did. This information gap couldn't help to conclude about the accuracy of the seasonal aggregation period in capturing same information on the ground. Hence, future validation about seasonal aggregation period should consider high frequency seasonal phenology observation in order to evaluate the seasonal aggregation period of the GIACIS project.

2. Flowering stage is the most drought affected crop development stage that signifies NDVI time series based crop insurance design should focus on flowering stage as it indicates crop yield condition. Early drought associated with late flowering may result in high yield. In this case shortening the seasonal aggregation without having information of the flowering stage time may lead to less accurate pay out calculation i.e. high amount of payout.

3. The application of different techniques showed that there is deviation between the crop loss and pay out between grid cells and within grid cells per farmer. As topographic conditions of the area

contribute to the deviation between crop loss and pay out, further validation is important in different locations of the same Crop Production System CPS) zone and check again the performance of the model. Conducting the validation on the same site also help to build confidence and generalize about the model. Topographic conditions should be considered at grid cell level and within grid cell because spatial variability exists at atom level (and beyond)

4. Since socio economic situations might have impact on the study result, further validation in same area or others should consider it.

5. Awareness about crop insurance should be created to the local farmers and governments officials through government structure before going for validation.

6. As the project has limited resource, the government should handle the task of validation and implement it through its structure. Training and other capacity building may be sought from partners. Validation by government has an advantage that government employees or other stakeholders might have information about farmers' crop condition and may challenge farmers when they give them unrealistic information.

7. Farmers give reliable information only to the people they know very well, so data collection should be done by the people who have close contact with farmers.

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7. APPENDICES

Appendix A: Grid cell based ranking results

118284

Bad year		Ranking coefficient
Loss	Payout	
2015	-	0.33
2008	2008	
2012	-	

118759

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	0.66
2010	-	
2015	2015	

119739

Bad year		Ranking coefficient
Loss	Payout	
2015	2015	0.66
2010	-	
2006	2006	

120740

Bad year		Ranking coefficient
Loss	Payout	
2015	2006	0.33
2010	-	
2008	2008	

121765

Bad year		Ranking coefficient
Loss	Payout	
2015	2015	0.66
2006	-	
2008	2008	

123351

Bad year		Ranking coefficient
Loss	Payout	
2011	-	0.66
2008	2008	
2015	2015	

124960

Bad year		Ranking coefficient
Loss	Payout	
2011	2015	1
2008	2011	
2006	2006	

125498

Bad year		Ranking coefficient
Loss	Payout	
2015	2015	1
2011	2008	
2008	2011	

127592

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	1
2011	2011	
2006	2006	

126551

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	1
2012	2012	
2006	2006	

127597

Bad year		Ranking coefficient
Loss	Payout	
2006	2006	0.33
2011	2010	
2015	2012	

123887

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	1
2015	2015	
2006	2006	

131272

Bad year		Ranking coefficient
Loss	Payout	
2015	2008	0.66
2006	2006	
2010	2010	

124422

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	1
2015	2015	
2006	2006	

128642

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	0.66
2010	2011	
2006	2006	

130754

Bad year		Ranking coefficient
Loss	Payout	
2008	2008	1
2010	2010	
2006	2006	

132842

Bad year		Ranking coefficient
Loss	Payout	
2010	2010	1
2008	2008	
2012	2012	

133375

Bad year		Ranking coefficient
Loss	Payout	
2010	2010	0.33
2012	2008	
2015	2011	

132850

Bad year		Ranking coefficient
Loss	Payout	
2006	2010	0.66
2010	2006	
2012	2009	

Appendix B: Field Form GIACIS: Drought Recall (2006-2015)

1 INTERVIEW DETAILS

Date interview: ____________________________ Name farmer: ___________________________

Name interviewer: _________________________ Sex: Male/Female: _____ Age: ________________

Season (local name of season considered in interview): # of years farming at location: _______________

____

2 FIELD LOCATION AND CROPS

Cell-ID:___________________ Latitude:________________°N Longitude: ________________°E

Main crops (circle): Teff Wheat Barley Maize Sorghum Other: _____________

Crop selected for recall (one of TWBMS): ________________________

Sowing date and month: ------------------------------Harvesting month-----------------------------

3 RECALL PART 1 (either Belg only, or Kiremt only!)

LAST 10 YEARS				
	Year (E.C.)	% of expected yield	Principal reason crop loss*	Timing**
Worst (of last 10 years)				
2nd worst				
3rd worst				
BAD YEARS BEFORE LAST 10 YEARS (farmer's own experience only!)				

** D: seasonal drought persisting over a large part of the season*
SDS: short drought spell at critical time
FL: flooding FR: frost
HA: hail PE: pest/diseases
WL: water logging - if other reasons: list them
- if PE, list name pest/disease

*** Multiple answers possible, use codes:*
SG: during normal sowing/germination time of crop
VD: during the vegetation development stage
FL: during the flowering stage
MA: during crop maturity/ripening before harvest

4. RECALL PART 2 (either Belg only, or Kiremt only!) for crop loss due to drought only as well

Year (E.C.)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Rating***										
xpected yield (%)										
Drought?										

5. FINAL

**** First explain rating to farmer & fill in with him/her →   0 = poor (no harvest)   5 = average   10 = bumper crop*

Personal judgement on #years (0 to 10) farmer could accurately recall: ______________ years

Willingness farmer to participate again in drought recall: yes / no

Telephone number farmer (if applicable and willing to share): ____________________________

Appendix C: Causes of yield reduction

Grid cell ID	Characteristic	Year of study									
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
				D				PE			D
	Crop loss cause							D			FL
											PE
	Crop loss	0.00	0	5.875	0	0	0	3.375	0	0	30.75
118284	Pay out	0.00	0	1.78	0	0	0	0	0	0	0
	Cause of crop loss	D		D		PE					D
											D+PE
	Crop loss	6.00	0	15.5	0	6.75	0	0	0	0	24.875
118759	Pay out	0.00	0	11	0	0	0	0	0	0	8.56
		D+PE		PE		PE					PE
	Cause of crop loss	D+FL		FL							D+PE
		D									D
	Crop loss	11	0	5.5	0	5.625	0	0	0	0	6.875
119739	Pay out	5.56	0	0	0	0	0	0	0	0	15.67
				D	PE	D	PE	PE			PE
								D			PE+FL
	Cause of crop loss							FL			D
								D+PE			
	Crop loss	0.00	0	9.5	4.625	9.375	3.875	6.25	0	0	32.875
120740	Pay out	1.78	0	5.56	0	0	0	0	0	0	0
		FL+PE		D							D
		PE		PE							
	Cause of crop loss	D+FL		D+FL							
		D									
	Crop loss	5.00	0	23.75	0	0	0	0	0	0	21.375
121765	Pay out	0.00	0	17.56	0	0	0	0	0	0	23.78
				D	PE		PE	D+PE	D		D
	Cause of crop loss							PE			D+PE
											PE
	Crop loss	0.00	0	10.50	5.00	0.00	6.25	2.38	0.75	0.00	8.75
123351	Pay out	0.00	0	9.22	0.00	0.00	0.00	0.00	0.00	0.00	15.89
		D+PE		D			D	PE			D
	Cause of crop loss	D					D+PE	SDS			
		SDS					SDS				
	Crop loss	40	0	18	0	0	20.5	6.5	0	0	9.625
124960	Pay out	28.11	0	20.22	0	6	21.33	0	0	0	35.11
	Cause of crop loss	D+PE		D			SDS	PE			D
							D				
	Crop loss	5	0	9	0	0	10.625	6	0	0	40.125
125498	Pay out	1.11	0	11	0	0	9.78	0	0	0	12.11
	Cause of crop loss	D+PE		D			D				D
		D					D+PE				
	Crop loss	13	0	19.625	0	0	12.875	0	0	0	6.375
127592	Pay out	6.67	0	17.44	0	0	11.67	0	0	0	0
		D+PE		D			D	D			D
	Cause of crop loss	D		D+PE			D+PE				
				D+FL							
	Crop loss	13	0	39.25	0	0	15	21.500	0	0	11
126551	Pay out	6.67	0	38.22	0	9.56	13.67	18.44	0	0	10.56
		D+FL					D	D			D+FL
	Cause of crop loss	D									D
		D+PE									
	Crop loss	36	0	5.25		0	20.375	15	0	0	24.75
127597	Pay out	26.78	0	4.56		16.56	15.67	26.33	0	0	0

Grid cell ID	Characteristic	Year of study									
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	Cause of crop loss	D		D	D+PE	PE		PE	PE		D
				PE	PE	FL+PE		D+PE			
	Crop loss	6	0	25.875	3.75	2.5	3.75	4.875	2.25	1.25	6.25
123887	Pay out	2.89	0	30.67	0	0	0	0	0	0	12
	Cause of crop loss	PE				D		PE			D+PE
		D						D+PE			
		D+PE						D			
	Crop loss	16	0	0	0	10.375	0	7.25	0	0	58.5
131272	Pay out	9	0	24.22	0	6.67	0	2	0	0	0
	Cause of crop loss	D+PE		D+PE			D				D
		D		D							
		D+FL									
	Crop loss	50	0	50	0	0	14	0	0	0	21.375
124422	Pay out	39.22	0	44.44	0	0	12.56	0	0	0	28.67
	Cause of crop loss	D		D		D+FL					D
						D+PE					
	Crop loss	41	0	39.625	0	8.625	0	0	0	0	3.75
128642	Pay out	33.67	0	32.56	0	4.44	26.33	11.56	0	0	0
	Cause of crop loss	D		D		D				PE+FL	
		D+PE				D+PE					
		SDS									
		D+FL									
	Crop loss	65	0	42.5	29.125	72.25	22	20.875	10	3.625	11.25
130754	Pay out	55.56	0	45.56	22.22	63.33	13.67	17.56	15	0	9.11
	Cause of crop loss			D+PE		D+FL	PE+FL	D+PE	D+PE		D
				D		D+PE					PE+FL
						D					
	Crop loss	0	0	15.5	0	20	8	11	6.25	4	9.25
132842	Pay out	0	0	10.22	0	16.22	0	2	0	0	0
	Cause of crop loss	D				D		PE		PE	D+PE
						PE		PE+FL			D
	Crop loss	6	0	0	0	35.125	0	31	0	5.75	20
133375	Pay out	1.11	0	11.22	0	38.89	7.11	0	1.11	0	0
	Cause of crop loss	D+PE				D		D	D		
		D				D+PE					
	Crop loss	41	0	0	0	46.25	0	19.875	8.625	0	6.875
132850	Pay out	30	0	0	12.22	55	24.22	16.44	7.78	0	0