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PROGRAMME EXPERIENCE

POVERTY

Developing Climate Services

Experiences in forecast use from Kenya, India and Nicaragua

christian aid

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ii) Acronyms

ANACC - Alianza Nicaragüense ante el Cambio Climático
CCSMKE - Christian Community Services Mount Kenya East
GCM - Global climate model/global circulation model
GEAG - Gorakhpur Environmental Action Group
GFCS - Global Framework for Climate Services
GHACOF - Greater Horn of Africa Climate Outlook Forum
GHG - Greenhouse gas
HFP - Humanitarian Futures Programme
IMD - Indian Meteorological Department
INETER - Instituto Nicaragüense de Estudios Territoriales
INTA - Instituto Nicaragüense de Tecnologia Agropecuaria
KARI - Kenya Agricultural Research Institute
KMD - Kenya Meteorological Department
MCN - Movimiento Communal Nicaragüense
MNREGA - Mahatma Gandhi National Rural Employment Guarantee Act
PRECIS - Providing Regional Climate for Impact Studies
PVCA - Participatory vulnerability and capacity assessment
RCM - Regional climate model
RCOF - Regional Climate Outlook Forum
SALI - Sustainable Agricultural Livelihoods Innovation
SMS - Short message service
SST - Sea surface temperature
WMO - World Meteorological Organisation

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1. Executive Summary

This report summarises the experience of Christian Aid-supported work across three countries – Kenya, India and Nicaragua. In Kenya, activities focused on supporting small-scale farmer access to the seasonal and 7 day forecasts whereas in India, the 5 day forecast was the key information product. In Nicaragua, development of a regional climate model to give longer-term agro-climatological scenarios was supplemented with capacity building through farmer-managed rain gauges and general training on climate change.

In Kenya, the basic hypothesis suggested that through the use of seasonal and short-term 7 day forecasts, farmers should be able to achieve a 10-20% yield improvement that can be reliably attributed to decisions changed by these forecasts. This reflected earlier research in Zimbabwe and Mali where farmers using climate services experienced similar or slightly higher productivity responses. Farmer groups received training as the seasonal forecast was released from climate experts from the Kenya Meteorology Department, the Humanitarian Futures Group, the University of Sussex and the UK Meteorology Office.

Although there were communication problems with the 7 day forecasts, which were introduced through an SMS-based system for the second season, all farmers reported receiving and using the seasonal forecasts. Decisions changed included (in order of importance) planting closer to the onset of rains; changing variety to increase drought resilience; changing crop to increase drought resilience; changing to conservation agriculture techniques to increase soil moisture; better timing of operations e.g. fertiliser application, pest control; changing planting regimes e.g. better plant spacing, rotation; increasing soil moisture through soil erosion control, water diversion; and increased use of manure. Both planting timing and timing of operations were also enhanced by the 7 day forecast.

About 94% of farmers attributed increases in crop output of greater than 5% to decisions they had made differently as a result of improved access to forecast information, mainly seasonal but also 7 day. Two-thirds felt that the impact on their crop production was greater than 15%, which tends to confirm the range proposed in the original hypothesis. A small number of farmers did estimate yield reductions – in one case, a farmer planted more green grams based on the forecast and an army worm outbreak had a negative impact. Another referred to waterlogged fields as a result of the heavy April rainfall period. Farmers assessed the forecasts as being 80-90% correct, so the review did not include a season where the forecast was significantly different from the actual seasonal performance.

In Uttar Pradesh, India, an SMS-based 5 day forecast together with relevant agricultural information is provided to farmers across 4 districts. The number receiving both directly and indirectly has expanded rapidly, with over 500 recipients forwarding the SMS to family and friends and others receiving the forecast from village noticeboards. Farmer groups have described their perceptions of the usefulness of five day forecasts, with a variety of impacts and an emphasis on cost savings through better management of inputs, pests and diseases, irrigation and risk mitigation measures. Although not all of these could be quantified, especially damage avoided, in all groups, specific examples of cost saving were cited. Perceptions of yields increase were less readily estimated but nevertheless, farmers were able to give conservative values of 10-25%, agreeing with the hypothesis proposed for Kenya.

There was also value expressed in terms of improving household resilience, something women group members emphasised, for both household food security and health. Elements highlighted by the participating communities as contributing to the success of the approach include the use of appropriate communication methods (SMS, village notice boards), the usefulness of the agro-meteorological information included with the forecast information and the feedback mechanism that ensures farmer groups have the opportunity to review the system monthly and feed back to GEAG. The skilled capacity of GEAG to design and deliver the system in partnership with the Indian Meteorological Department and local universities is also crucial, but this does in itself raise issues as to the long-term sustainability of the service.

Climate services are provided through the participatory and vulnerability assessment (PVCA) process. Given the importance of climate-related shocks and stresses to the risk profiles generated, it is not completely unsurprising that climate services have generated the interest and usefulness that they have. Whilst this review did not specifically focus on evaluating the PVCA processes, it has clearly been closely and effectively integrated with climate services, defining the framework for their delivery at community level. However, the evidence base for climate service effectiveness does need to be deepened beyond the encouraging findings presented here. Better impact data for seasonal and short-term forecasts, especially quantitative evidence is needed to conclude with greater certainty whether or not climate services are having the impacts shown, especially with respect to improved productivity and income.

In Nicaragua by contrast, Centro-Humboldt have developed a regional climate model (RCM) using PRECIS software developed by the UK Meteorology Office and applied it to scenarios from 2014-19 to 2034-39 for Bosowas Biosphere Reserve forests and the main staple crops of maize, beans and rice. A contraction in the area suitable for maize and beans, in particular the areas considered optimal but also a fragmentation of areas considered suitable, is shown with the suitable area in the central highlands shrinking and shifting eastwards. This then encounters geographical constraints as the agro-ecology changes to lowland rainforest, which is unsuitable for these two crops. The net effect of climate change is therefore a crop area that is being squeezed between increasing drought pressures (reduced rainfall, increased temperatures) and the restrictions of geography in migrating east.

The trend for rice does show some variation from maize and beans with both fragmentation and expansion. Suitable areas in the western side of the country decline but the potential area expands south in the eastern parts. This has implications for rainforest conservation, given its important role in climate regulation and as a source of valuable genetic biodiversity. Movimiento Communal Nicaragüense (MCN) have also been involved in a statistical downscaling exercise which also reaches the same conclusions about increased drought stress in the highland areas of Matagalpa.

The RCM has also been informed by a network of 27 community-managed rain gauges, who are also using their rain gauge records to make yield-enhancing decisions that include matching rainfall to the phenological characteristics of crops to guide crop management measures; using the data to determine the type and variety of crops to plant; better estimation of the planting date; early warning of drought conditions to guide planting and irrigation decisions; early warning of flood risks; and to review harvest prospects based on rainfall records to give an early indication of harvest expectations. Yield data from Nochari indicated a 75% yield improvement that has been partly attributed to improved climate and rain gauge information and also adoption of agro-ecological methods such as use of organic fertilisers and pesticides, better access to seed through seed banks and training provided on what to plant when. Future priorities are to extend the results of the climate model to the communities involved so that they can use it to inform longer-term planning as part of the development or renewal of their PVCA-based development plans. Opportunities to increase the scope of climate services could include adding short-term and seasonal forecasts to the package.

2. Developing Climate Services in Kenya

2.1 Intervention area background

Christian Community Services Mount Kenya East (CCSMKE) initially developed the Sustainable Agricultural Livelihoods Innovation (SALI) project as a marketing intervention with farmer groups in the more marginalised, semi-arid parts of Embu County in central Kenya. The increasing climate challenges to crop production led to farmer groups requesting additional support to improve their capacity to manage climate variation as an essential component of activities to increase their access to markets. Mbeere District is predominantly agricultural, with crop production supplemented by free-range cattle, goats and poultry. In the northern parts of the district (Karii, Siakago, Kerwa), holding sizes vary, from 2-3 acres being an average holding, ½-1 acre considered small or very small, 4-7 acres large and anything over 10 acres very large. In the southern areas of the District (Gategi, Kithenya), holding sizes are generally larger, with 5-10 acres considered average, 3 acres small and 1-2 acres very small. Over 10 acres is viewed as large, with over 100 acres very large. Groups involved in the climate services work tended to have membership predominantly in the average holding size category with some (up to 20%) in the smaller categories and a smaller number (10% or less) in the large category.

Crops grown vary from area to area – farmers in the northern part of the district cultivate mainly red laterite soils whereas in the south, heavier black cotton soils are more prevalent. The south is more recently settled and so land tenure here is less formalised. Maize, cow peas, green grams, beans and sorghum are the predominant crops, all grown for both food security and cash. Cotton has declined substantially in both seasons as a result of past marketing failures. Pigeon peas are valued by farmers for their drought resilience, with both cassava and particularly dorico beans seen as emerging crops due to their value for both food security and cash cropping. Bullrush was identified as the more suitable millet for the area, with demonstration plot trials in finger millet not performing well.

Long rains cropping has changed substantially in the last five years due to an experienced decline in rainfall reliability. Farmers increasingly view the season as an opportunity to supplement food security with drought-resistant pulses or sorghum, or to focus on green grams as a cash crop. General responses to diminishing and less reliable long rains have included:

- More green grams, less maize due to reduced levels of rainfall.
- More sorghum, less millet as sorghum survives dry spells better.
- Change from local to hybrid maize varieties, to test for drought resilience.
- More sorghum and millet, less maize generally.
- Ceased bean cultivation, reduced area allocated to maize.

2.2 Project implementation

The first season of the project began in August 2011. Both community and national workshops were organised by Christian Aid, CCSMKE and the Humanitarian Futures Programme (HFP) with participation from both international and local climate scientists[1] with the objectives of:

- Strengthening understanding of the current levels of certainty and uncertainty within seasonal forecasting and other relevant areas of climate science amongst

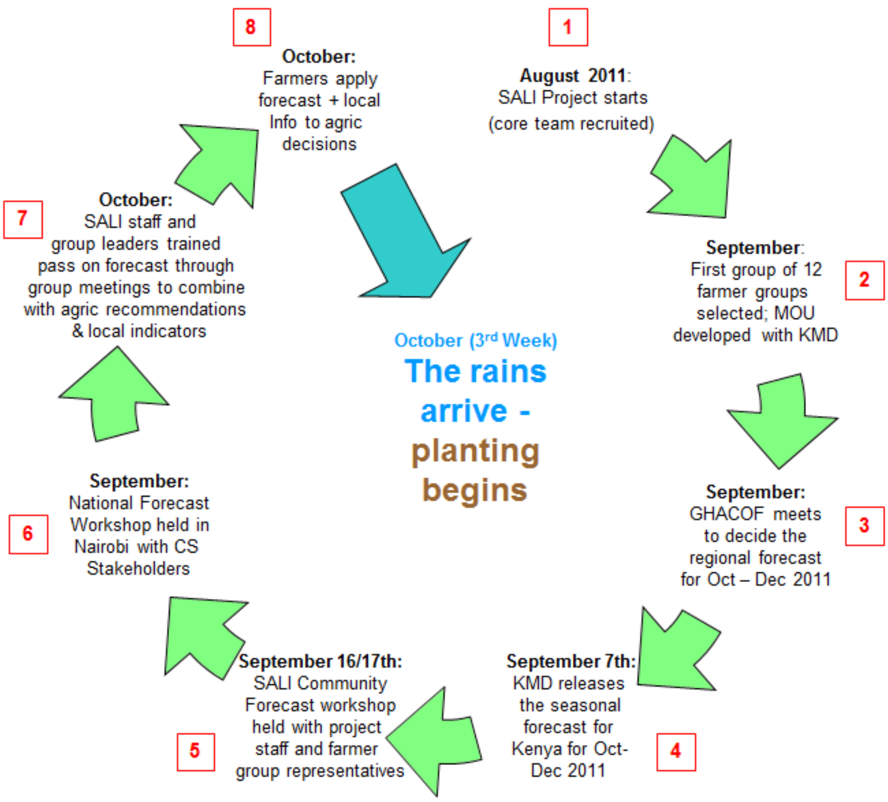
[1] For the 2011 short rains, five CCSMKE staff with 20 farmer group representatives from the 12 groups.

farmers groups participating in the project, as well as CCSMKE and Christian Aid project staff.

- Developing an agreed framework for delivering regularly updated climate information to participating farmer groups over the course of the 2011 short and 2012 long rains seasons, and …
- Supporting effective application of seasonal forecasts and other relevant climate information.

With seasonal forecasts, making the most of the window of opportunity between the release of the seasonal forecast by the Greater Horn of Africa Climate Outlook Forum (GHACOF) and the Kenya Meteorological Department (KMD) and the onset of rains proved a critical part of activity implementation (as per Fig 1).

Fig 1. Timeline for seasonal forecasting activities



For the second long rains season, stages 3 to 8 essentially followed the same process but this was enhanced by additional field staff (group facilitators) that joined the project in February. However, with the GHACOF meeting at the end of February and seasonal forecasts announced at the beginning of March, the window of opportunity to effectively disseminate the information and facilitate its application by the project's farmer groups before the anticipated start of rains in the third week of March was about half – three weeks versus six weeks - the equivalent period for the short rains process.

2.2 Understanding the seasonal forecast

All groups cited a number of changes to climate that they have experienced, particularly over the past 5 years (see Fig 2 below). Summarising the five basic changes in climate phenomena that the farmer groups have highlighted, it is clear that rainfall change in terms of amount, reliability and intensity are perceived as causing the most impact, followed by increased temperatures at the end of dry seasons/start of rainy seasons. These were unanimously attributed to an increase in deforestation upsetting the local climate, as forest cover is removed to cater for the expanding need for agricultural land, brick-making and charcoal production. Groups in the northern part of the district also mentioned sand extraction from rivers as a possible reason, although this is more likely perceived as a cause of water resource loss rather than having direct impact on local climate. Two groups mentioned that they had heard something about pollution from industry causing climate change and one suggested that the rotation of the earth had altered, changing weather patterns.

Fig 2. Farmer perception of climate changes[2]

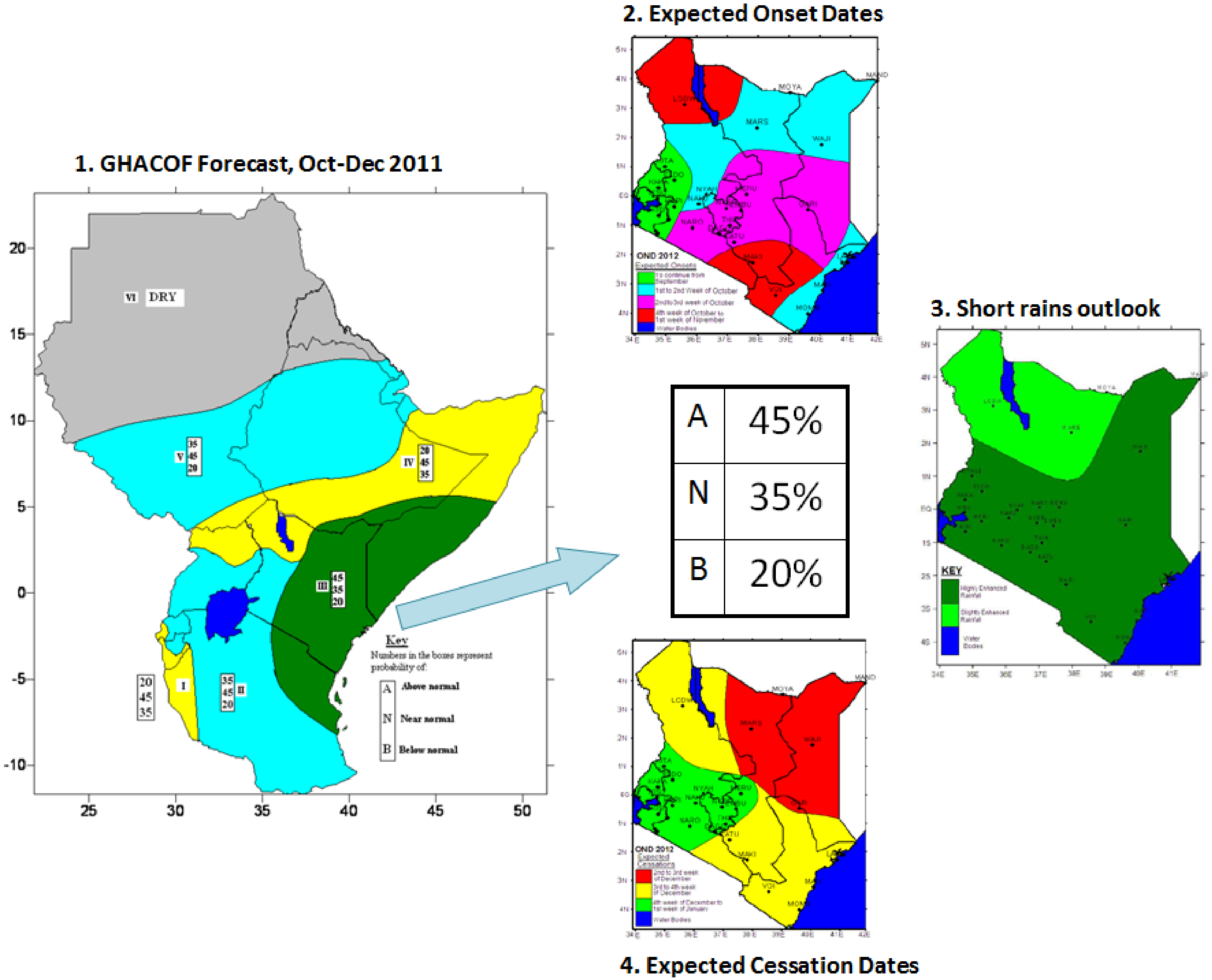
Climate phenomenon	Summary of change	Ranking score
Rainfall	Less predictable, shorter rainy seasons, more intensive rainfall followed by extended dry spells	34
Temperature	Hotter at the end of the dry seasons, not as cold in the cold season, unusual post-rainfall drops in temperature	22
Wind	Stronger, changing direction, dustier with destructive whirlwinds more likely at the end of the dry season	10
Seasonality	Long rains and short rains seasons swapping over	6
Cloudiness	Rainless cloudy weather increasing	1

The seasonal forecast[3] for the 2011 short rains season took into account the decaying La Niña conditions in the Equatorial Pacific Ocean, warmer than average sea surface temperatures (SSTs) in the western Equatorial Indian Ocean (near to the East African coastline) and forecasts based on models from the international forecasting centres (such as the UK Met Office). Expected start, distribution of rainfall and end dates were derived from statistical analysis of past (analogue) years, which exhibited similar characteristics to 2011. As a result, for the 2011 short rains, the forecast was for generally normal to above normal rainfall across the country[4] – *"the outlook for October-November-December (OND) 2011 Short Rains Season indicates that most parts of the country are likely to experience near-normal rainfall. Enhanced rainfall is, however, expected over the Coastal strip, Southeastern lowlands and the central highlands including Nairobi. The distribution, both in time and space, is expected to be generally good over most areas except in the Northeastern and Northwestern regions."*

More specifically for the area of central Kenya including Mbeere District, the forecast concluded that they were *"likely to receive near-normal rainfall with a tendency to above-normal (enhanced rainfall)"*. In terms of onset and cessation, the Mbeere area would *"experience their onsets in the third to fourth week of October. The rains are likely to cease during the third to fourth week of December".* Farmers were asked to *"work closely with the Ministry of Agriculture and take advantage of the expected good rainfall performance to grow long duration crops which will maximize on the crop yield".*

[2] Numbers after each change reflect the importance of their impact on agriculture, as agreed by the groups
[3] Regional maps (in Fig 3) are from the ICPAC Greater Horn of Africa Climate Outlook Forum (GHACOF) Statements 29 (SR, 2011); Kenya maps are from the KMD Outlooks for Oct-Nov-Dec 2011
[4] Source: Kenya Meteorological Department

Fig 3. Seasonal forecast maps, 2011 short rains[5]



[5] Source: Greater Horn Regional Climate Outlook Forum/Kenya Meteorological Department

So farmers in Mbeere could expect an 80% likelihood[6] of average to above average amounts of rainfall, largely falling in a consistent pattern between the third week of October and the third week of December, compared to just a 55% likelihood[7] of average to below average rainfall (see Fig 3 above). The forecast for the following long rains from March to May 2012 were the opposite of the previous season, with a 45% likelihood of below normal rainfall but only a 20% likelihood of above normal. So farmers could expect an 80% likelihood of average to below average amounts of rainfall and a 55% likelihood of average to above average rainfall. This depressed rainfall outlook would see rains arrive in the 2nd to 3rd week of March and finish in the 2nd to 3rd week of May.

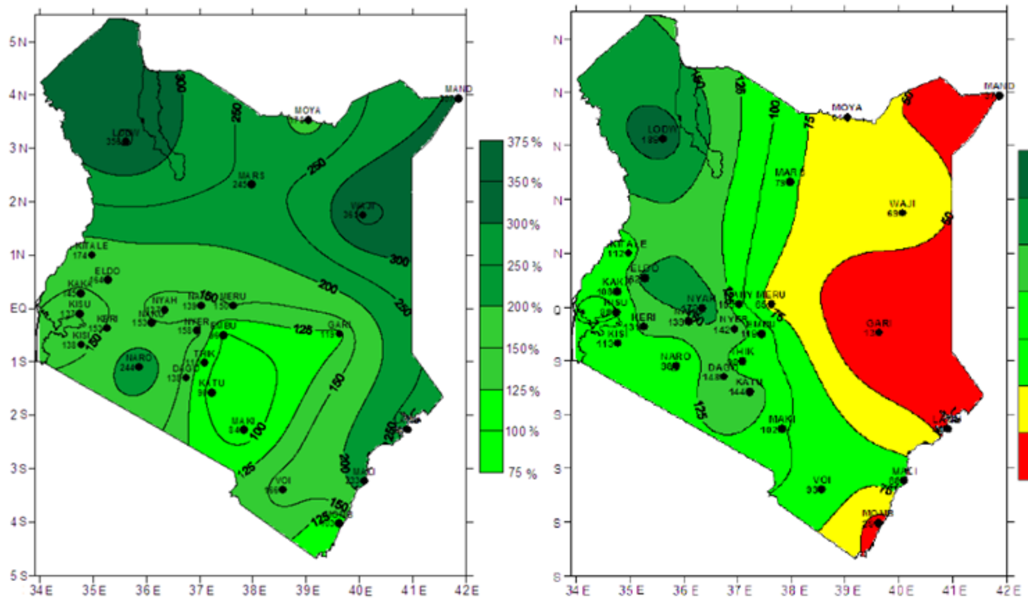
2.3 Performance of the seasons

Analysis of the Oct-Dec short rains season[8] shows that the rainfall performance was generally good nationwide (see LH chart in Fig 4 below). Some areas in the north-east (including Wajir and Mandera) received 300% of their long term averages, others (Lamu, Marsabit) 200%. Interestingly, of the two stations nearest to Mbeere, Meru recorded the highest rainfall in the country of 1,034 mm (150% of average) while Embu was one of the few that did not exceed 100%. The March – May long rains had a forecast that was the mirror image of the previous season and actual performance (see RH chart in Fig 4 below) split the country between a much drier east and a wetter west, albeit from rainfall that was characterised by intense episodes in the second half of the season causing severe flooding in central and western highland areas. The total rainfall amounts recorded in March barely exceeded 50% of the average at most meteorological stations. In contrast to the short rains, the north-east received record low levels. Only 19.2mm (13%) was recorded at Garissa Meteorological Station, the second lowest seasonal rainfall total in 53 years. The heaviest storm of 105.5mm was recorded at Embu station on 16th May, this being the highest May total since 1976.

In Mbeere District, rainfall data for the year as a whole compared to the average (2006-2009)[9] shows that while the short rains delivered 97% of expected rainfall, this dropped to just 70% for the long rains. The "between the seasons" period of December to March delivered just 9% of average rainfall, reflecting the early cessation of the short rains and the late start of the long rains, giving a prolonged 4 month dry season. Rainfall intensity was also a noted characteristic (see Fig 5 below). Twenty five percent of long rains precipitation fell on just 3 consecutive days in April and extended dry spells occurred between rainfall events. The short rains delivered 17% more rain but effectively 45% more - 51 versus 35 - useable growing season days. There is a note of caution with this comparison as this compares only one station (Kiritiri) with the district average but the figures broadly agree with the results shown in Fig 4 and confirms the assessments of both seasons by the farmers interviewed.

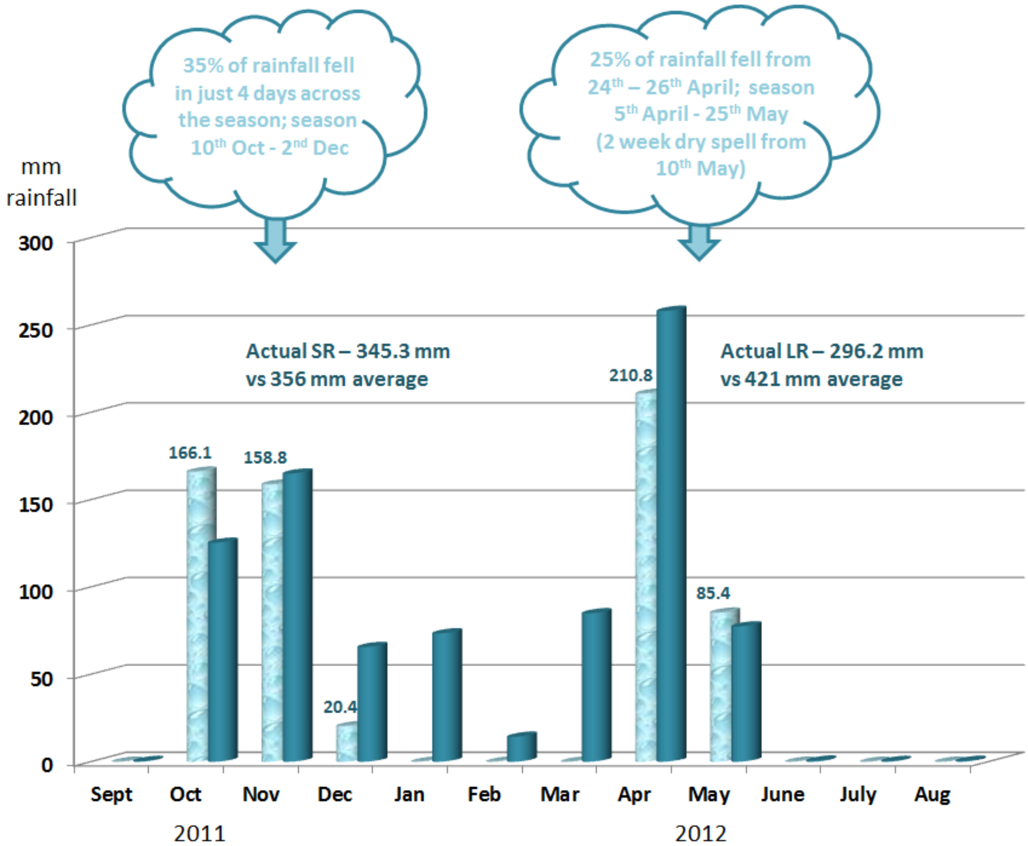
[6] Combining the normal and above average terciles
[7] Combining the normal and below average terciles
[8] Source: The Outlook for MAM Long Rains Season 2012 – KMD (2012)
[9] Source: Drought Monitoring Bulletin (Ministry for the Development of Northern Kenya)

Fig 4. Actual rains for both seasons[10]



Actual Rains, OND 2011 Actual Rains, MAM 2012

Fig 5. Rains for 2011/12 versus the District average[11] *(solid colour = average rainfall 2006-2009; light blue pattern = actual rainfall, 2011/12)*



[10] Source: Kenya Meteorological Department
[11] Source: Kiritiri Agricultural Station, Ministry of Agriculture, Mbeere District

2.4 Use of local indicators

Local indicators are widely recognised and used by the community as a whole. There used to be specific individuals that had *"powers"* to forecast the rains, but these practices have died out due to a combination of modern education, increased use of scientific forecasts, modern media and the influence of the church. However, local indicators have persisted as general knowledge although in some cases, such as the behaviour of certain stars, groups referred to their oldest members for specific descriptions.

Fig 6. Local indicators and their meaning

Phenomenon	Timing	Meaning	Score	Notes
Acacia trees flower	Feb & Sept	Rains are near	31	Heavy flowering can mean heavy rainy season
Dragon flies appear and fly low	Feb/Mar & Oct	Rains are near	21	
Swallows appear in numbers, swooping around	Mar & Sept	Rains are near, 15 days to rain	16	
Medium-sized brown bird with long tail starts calling	Oct only	Rains are near	11	
Frogs start croaking	Mar & Sept	Rains are near	10	If a certain small frog calls, a flood can be expected
White and black ants appear, moving nest	Feb & Sept	Rains are near	8	
Trees sprout leaves	Feb & Sept	Rains are near	7	Muvuti, Mutiru and Mukuyu (fig) trees
Dark cumulus clouds are building	Feb/Mar & Sept/Oct	Rains are near	6	
Parrots start flying about, chattering a lot	Feb/Mar & Oct	Rains are near	5	
Bees migrating	Feb/Mar & Sept/Oct	Rains are near	5	
Cool immediately after onset of rain; sound carries far	After first rains	Expect a good rainy season	4	
Strong halo around the moon	Mar & Sept	Enough rain will fall	3	
Livestock jump about	Before rainfall	It's about to rain	3	
Rainbows appear	During the season	Small - lots of rain; big (180°) - poor rains	3	
Strong halo around the sun	Mar & Sept	Drought	2	
Movement of star S to N, movement of star, SW to NE	Feb & Sept	N to S - Low rainfall, drought; SW to NE - heavy rains	2	

Star appears to the west, low in the sky	During the season	Poor rains, hunger	1	
Water rising in well	Feb & Sept	Rising - rain is near; no rise - drought	1	

Groups identified a total of 18 local indicators (see Fig 6 above). Of these, the 10 considered most reliable are all used to assess when the rains will arrive, a constant preoccupation as the rainy seasons approach. Of the 8 least reliable indicators, 7 are used to assess whether the rainy season will be good with plenty of rain or a bad, possibly drought season. The most reliable indicator is the flowering behaviour of acacia trees, with leaf emergence in other species also highlighted. Of the other top ten local indicators, three covered the behaviour of various bird species and three used the behaviour of various species of insects.

One involved the behaviour of amphibians, although there was some discussion as to whether the emergence of croaking frogs was as a result of rains arriving or in anticipation of it. Either way, frogs were thought to emerge only if regular rainfall was expected, suggesting that this indicator is has an additional use in addition to the other *"rains are near"* type indicators. One particular frog call was described as only being heard if very heavy rains or floods are due. Notably, indicators involving the appearance or movement of stars were only known by older members of the groups.

Brickmaking accelerates deforestation, removing the tree species used to forecast weather and (according to the local community) causing climate change

The relatively low reliability ascribed to those indicators predicting seasonal characteristics suggests that combining the scientific forecast with local knowledge is more about each filling gaps in the others coverage, rather than reconciling potentially antagonistic predictions. In other areas of Kenya, local indicators that are used to predict the nature of the season are used and so there may be scope in identifying "new" local indicators that also work in the Mbeere area. All groups confirmed that local indicators were still useful and their reliability was not perceived to have deteriorated due to the climate changes they have experienced over the past 5 years. However land use changes had affected their use. Deforestation was especially highlighted in relation to using acacia trees – if these were no longer present or as common as they used to be, it was difficult to continue using them.

After the short rains, three of the five groups felt that if asked to choose between local indicators and the scientific forecast, they would choose their local indicators, largely because these could be physically observed and so were more relevant to the local area than the large-scale seasonal forecast. All groups, and especially the two that rated the scientific forecast more highly (although one of these qualified their response with a near 50:50 answer), said that there was a need to understand the figures and details in the forecast so that they could use it better. After the long rains (the second season using the KMD forecasts), there was a noticeable change in perceptions, with four out of the five groups clearly favouring the scientific forecast over their local indicators. Their reasons included:

- greater familiarity with the scientific forecast enabling a better understanding.
- the opportunity to interact directly with meteorologists and agricultural advisors, enabling farmers to ask questions about the forecast and the best agricultural recommendations. As one farmer noted in reference to the radio forecast *"you can't ask a radio questions"*.
- openness to combining science with local knowledge, so farmers didn't feel they were simply being told what to do.
- the accuracy of both seasonal and 7 day forecasts, generally viewed as 80-90% reliable.
- the loss of local indicators to land use changes, such as deforestation reducing the occurrence of acacia tree species.

One feature highlighted when reviewing the agricultural performance of the short rains was the prevalence of army worm infestation towards the end of the season (late November, early December). Farmers indicated that this was to be expected following a severe drought season, so could have been the subject of a climate-related early warning to reduce its impact. As it was, farmers that planted early maturing varieties (somewhat contrary to the recommendation with the forecast) withstood the army worm better. The early cessation of the rains compounded the infestation – farmers referred to previous outbreaks that were curtailed by ongoing heavy rains, but with the end of the rains coinciding with the outbreak, it was more persistent than usual. Despite the long rains being poor, farmers still emphasised the usefulness of being able to receive the forecasts but highlighted the need for small-scale irrigation to supplement their management practices in drought seasons.

2.5 Communicating the forecast

In terms of the kind of information to be communicated better in future, group members put most emphasis on the seasonal forecast as it could be used for key pre-season (and therefore difficult to reverse) planning decisions, such as what crops to plant. In addition, both adequate supply and choice of seed was emphasised – without this, farmers cannot act on the seasonal forecast very effectively. Mobile phones were recommended as *"everybody has one"* with some farmers initially aware that a daily forecast service is available for KSh 7 per forecast. The general feeling was that this was poor value when it was not specific to their area. With the introduction of the SMS seven day forecast in the long rains season, the views on this method of communication had changed significantly by the second season with mobiles moving up to the 3rd most favoured communication method.

Fig 7. Methods of communicating forecasts

Method	Neema	Utugia	Kerwa	Uweso	Kawama	Kaam	Karagare	Score
Direct group training by a forecast expert	4	4	4	4		3	4	23
Radio (esp. early morning or evening)	1	1	3	2	4	4	3	18
Mobile phones		3	2		2	2		9
Barazas (venue for agric staff to give recommendations)	3		1		3			7
From an agricultural advisor				3		1		4
Through farming magazines (e.g. Spor, Farming Matters)		2						2
Posters (in local languages)	2							2
On TV				1		1		2
Through church			1					1

Direct training was the most favoured, at least initially, as this would reach all group members. Despite reservations, radios were considered useful for both seasonal and short-term forecasts but it was pointed out that not everyone owns a radio, not all stations broadcast the forecast at a convenient time and people have different preferences for stations, some of which might not carry the forecast. The general view was that radio forecasts have to be substantially upgraded, with more explanation and new formats, such as an agro-meteorological forecast where farmers can ring in to ask questions or be involved in the programme, discussing the forecast, its uncertainties and the agricultural recommendations that are developed.

Barazas were highlighted as venues that can reach the whole community and through which the forecast together with local agricultural recommendations can be passed. However, group members expressed concern about the level of meteorological training that agricultural extension staff have received and the *"demand-led"* nature of the extension service. In practice, this has proved difficult to access, partly due to the reduced coverage of extension officers – typically the ratio is now one advisor for 1,400 farmers. A gradual process of encouraging private local service providers, based partly on systems developed for animal health services, was initiated in 2012. There are aims to expand this approach to soil conservation and in future other advice, such as climate services, if appropriate. However farmers had doubts about paying for forecasts, especially for group members operating smaller holding sizes, feeling that this sort of information should be recognised as a public good given its importance to lives e.g. during drought years, as well as livelihoods.

When asked about the possibilities of combining the scientific forecast with local indicators, all groups agreed that when both sources agree with each other, this increased their confidence to apply the information to decision-making. Some were concerned that where they disagree, there might be confusion. Two groups highlighted the need for a mechanism to blend both forecasts and all groups confirmed that if they could obtain rain gauges, this would assist in developing a greater understanding of rainfall patterns, ways of assessing cumulative rainfall so that they could improve planting time decisions and developing a historical record that they can use together with their local indicators.

2.6 User experience and impact

For both the 2011 short rains and the 2012 long rains, all members confirmed that they had representatives at the SALI project seasonal forecast workshops. The success in relaying that information back to the wider group membership was mixed for the short rains but more effective for the long rains. Although the shorter-term 7 day forecast was not generally used in the first season, the SMS system was established for the long rains. This involved installing software from Frontline SMS onto the project computer in Siakago. A tailored forecast for Mbeere was released every 7 days by the Kenya Meteorology Department and communicated via Christian Aid to the project computer, which then relayed it to every farmer group members' mobile phone number logged into the system.

Discussing the usefulness of the long rains forecast

For the seasonal forecasts, none of the groups received the numerical forecast (as in the above, normal and below % format show in Fig 3). For the short rains, about 45% of group members received the forecast as a part of the pre-season extension work carried out by the project. The remaining 55% either received the forecast indirectly, usually through discussions as part of the demonstration plot establishment process, or from previously used channels, such as the radio. For the second season of the project, 100% of group members reported receiving a formal training on the long rains forecast. However, the window of opportunity was clearly tighter – the GHACOF released the forecast at the beginning of March indicating an onset of rains in the third week. This effectively left only 3 weeks to run national and local level workshops to relay the forecast with training and agricultural recommendations. During the review of the second season, all groups interviewed emphasised that while they were still able to make pre-season decisions about input purchase, they received the forecast about 2 weeks before the rains when ideally, a seasonal forecast should be received at least 4 weeks advance.

For the 7 days forecast transmitted by SMS there were some communication problems. Farmers reported a somewhat intermittent service, with some only receiving between one and three forecasts out of nine for the season. In some cases, this was due to breaks in the communication chain from KMD to the farmers and in others, due to the need to download text messages within 24 hours of receipt, after which Safaricom deleted the message. Farmers indicated that they either did not remember and therefore missed the download time or that phone charging was sometimes difficult in rural areas and this caused them to miss the text.

On-farm trials of the 9 seed hole (post-harvest)

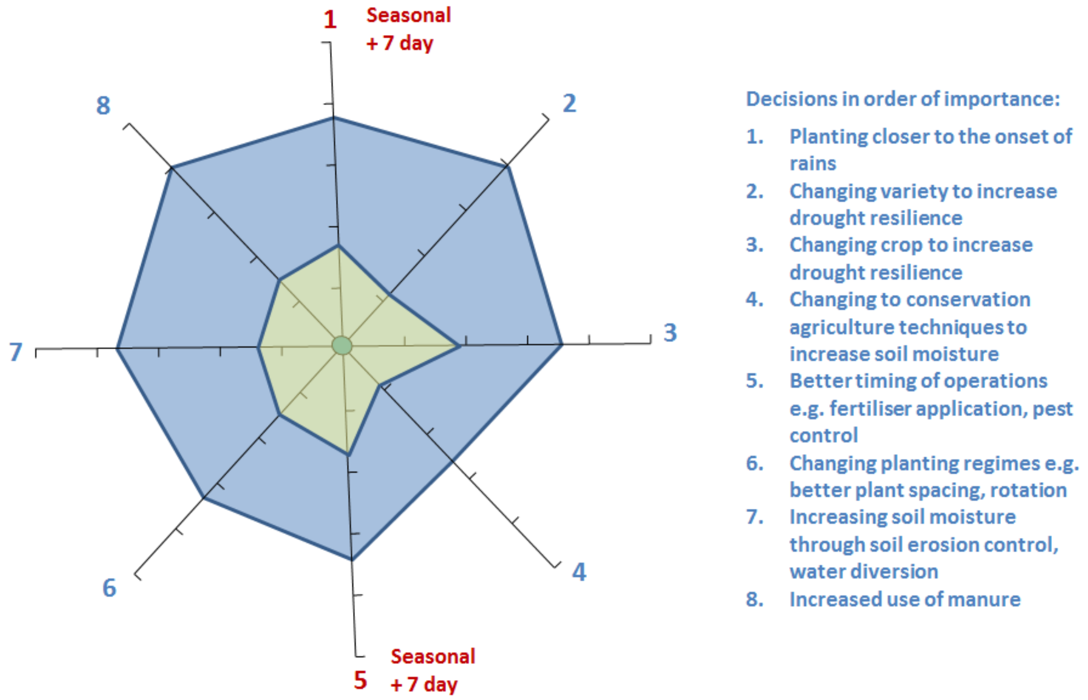
For the first short rains season, the decisions that were informed by the forecast fell into three main categories – planting early to take advantage of an anticipated early start to the season; planting either early-maturing or drought-tolerant crops that can withstand any possible early cessation of rains; and increasing the focus of moisture conservation through terrace repair and some water harvesting-type operations. Interestingly, the groups in mixed farming areas put greater emphasis on drought-tolerance, with both Neema and Utugia emphasising the use of the 9 seed hole[12] for maize production trials in their demonstration plots of the season, demonstrating its water conservation credentials. Utugia still had maize maturing in 9 seed holes for harvest two months after the end of the season.

For the second season, the review included groups themselves carrying out spider diagram exercises to identify those decisions that were directly affected by the forecast and score themselves on how effectively they made this decision both before the SALI project (i.e. in previous seasons) and after. These individual group spider diagrams were then aggregated into one (see Fig 8 below). The main benefits result from being able to time planting more precisely and to make adjustments in both the crops and the varieties of those crops grown so that they better suited anticipated seasonal conditions. That varietal change scored

[12] The 9 seed hole is a conservation agriculture technique involving the preparation of a square hole 12 – 18 inches deep, 2ft x 2ft wide, with 3 seeds planted along each edge and one in the middle. Manure is added to leave a shallower hole that collects and conserves moisture and nutrients.

better than changing crop type completely indicates a preference for incremental change rather than wholesale switching. However farmers are clearly making some quite radical changes e.g. more drought-tolerant crops such as sorghum and millet at the expense of maize. The remaining decisions largely related to land management processes designed to increase resilience to low or erratic rainfall.

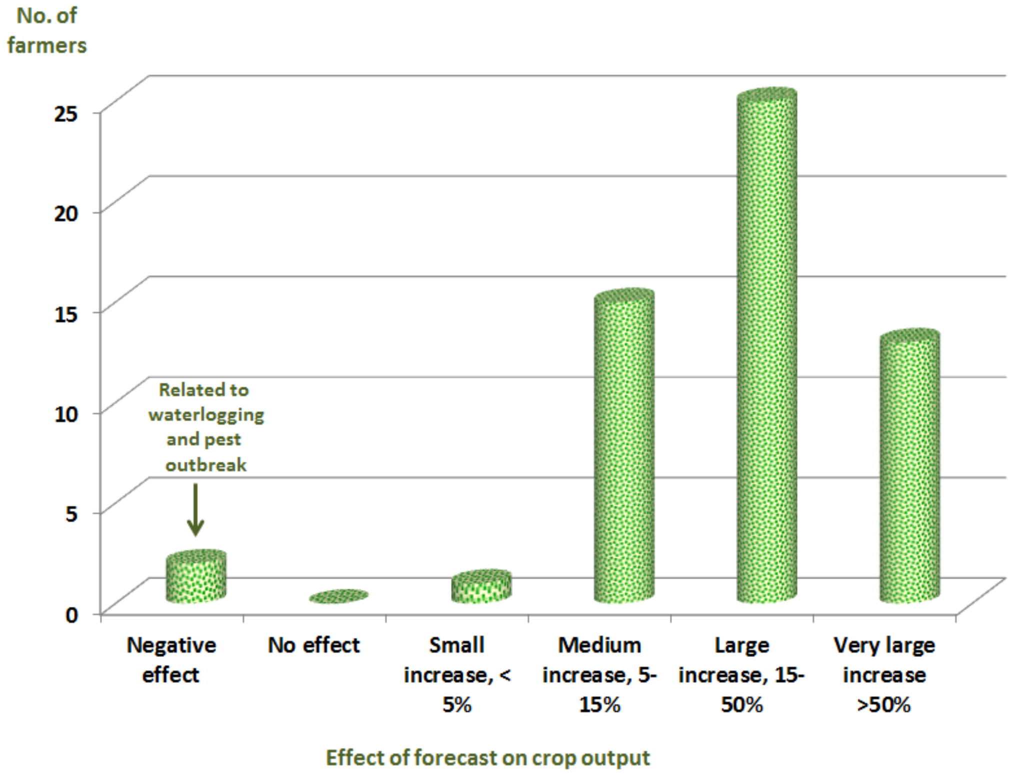
Fig 8. Farming decisions as a result of receiving the forecast



Despite challenges with transmission, the 7 day forecast was viewed as particularly useful. Farmers seemed to like the method of distribution (as per Fig 7) and indicated that they had some confidence in a forecast that was designed for their area and had clear information on the past seven days and the next seven. This forecast was seen as particularly useful for issues of timing – for planting (fine tuning the start date provided by the seasonal forecast), pest control and fertiliser application. When asked if forecasts were more critical for some crop options than others, farmers highlighted maize and beans as crop choices that would be relatively more sensitive to forecast information due to their lower resilience to poor rainfall. Millet was also highlighted, with planting delayed if heavy rainfall was forecast to avoid destruction of seedlings and planting timing modified to avoid rotting of the harvest by late rains.

The key impact is, of course, whether these decision changes result in increased productivity. After encouraging anecdotal feedback after the first season, the long rains review asked farmers to assess the decisions they had made differently due to forecasts in terms of yield – whether they attributed a small increase, a more significant effect or even a negative impact. 94% of farmers attributed increases in crop output of greater than 5% to decisions they had made differently as a result of improved access to forecast information, mainly seasonal but also 7 day (see Fig 9 below). About two-thirds felt that the impact on their crop production was greater than 15%. A small number did estimate yield reductions – in one case, a farmer planted more green grams based on the forecast and an army worm outbreak had a negative impact. Another referred to waterlogged fields as a result of the heavy April rainfall period (as per Fig 5 above).

Fig 9. Farmer attribution of increased yield to decision change made based on forecast information



When discussing yield improvements, farmers were clear about how and why a forecast-informed decision resulted in increased output. This strengthened the attribution of forecast use to yield improvements, but clearly using this qualitative technique to assess the productivity increase due to climate forecasts raises questions of whether the same impact would be detected through use of more in-depth quantitative investigation. A sample survey using statistical methods would also have challenges - including over-estimation of yield due to in-field measuring biases, the difficulty of finding equivalent control values to compare and the moral hazard of attempting to use control groups that would have to be denied access to forecasts to be valid. But these results do support the basic hypothesis of a 10-20% yield impact and suggest that more in-depth assessment would add significance to these findings.

2.7 Farmer recommendations

Groups were asked to highlight their direct recommendations for future seasons in terms of two categories – firstly, the future communication and use of short-term and seasonal forecasts and secondly, the kind of supplementary agricultural information services they would need to take advantage of forecasts in the most effective way.

In the first category, farmers raised the following issues:

- A seasonal forecast needs to be transmitted to farmers ideally a month before rainfall onset. Two weeks is a minimum but is really not enough to inform all pre-season decisions. This implies moving the Regional Climate Outlook Forum for the long rains at the beginning of March back two weeks to early to mid-February.
- A concern that farmers are not seeing the probabilities so that they can understand the level of uncertainty contained in the seasonal forecast. This raises the risk of

providing a deterministic forecast based on probabilistic information which, if perceived as “wrong”, reduces forecast user confidence. Farmers that had discussed the uncertainty of forecasting indicated that they did understand it, and with the right advice, could navigate their way towards “best bet” decisions.

- A more reliable supply of 7 day forecasts that can be received by all group members, not just one or two. These are less susceptible to uncertainty and so can be used to fine-tune operations, especially planting dates. Likewise, the date of transmission should be widely known so that farmers can switch on their mobile phones at the right time and get the SMS before it is deleted by Safaricom.
- More location-specific information, and preferably a KMD sub-station that can act as a resource for local farmers in the District. Farmer groups could receive rain gauges and training on their use, so that they use the information themselves and feed it to a local sub-station.
- Booklets and bulletins in the local language that can be used to increase understanding of the forecast and distributed through good local networks, especially the church.
- Develop a seasonal forecast and monthly update in a format that can be sent via SMS (as with the 7 day forecasts).
- Ensure that contact farmers are identified for the SMS, so that they can make sure any group members that do not own mobile phones are not left out.

In the second category, farmers recommended:

- An increase in affordable soil testing services – the current fee is too high for this essential service to be used widely. The high soil diversity in the area needs regular nutrient and pH testing. This was highlighted as the top priority.
- Measures to increase seed supply and the right selection of seeds based on the forecast – this implies providing forecasts to input suppliers as well as farmers. Groups also suggested seed banking as a measure to mitigate local seed shortages. Seed supply was generally the second priority concern.

- On-farm research into the crops and varieties that work – recommendations seem to be *"standards"* for the wider area and not relevant to Mbeere District.
- Increased technical support with small-scale irrigation, water harvesting and conservation agriculture methods and to reduce vulnerability to drought, extended intra-seasonal dry spells and early rainfall cessation.
- Advice on reforestation, climate and environmental change – primarily to restore lost forests and the micro-climate regulation services they provide.
- Other suggestions included the better integration of livestock and increased knowledge on integrated pest management as pesticides are too expensive for most group members. These were more general issues rather than specifically related to climate services.

3. Developing Climate Services in India

3.1 Intervention area background

Gorakhpur Environmental Action Group (GEAG)[13] has been supporting the development of environmentally sustainable agriculture in Uttar Pradesh since the early 1970s. In 2011, in response to increasing farmer concerns about climate variation and its impact on the resilience of small-scale farmers, GEAG initiated an intervention across 4 districts in the eastern part of the State to increase farmer access to 5-day forecasts. This is an area in the Ganges floodplain of northern India that is particularly susceptible to flooding during the annual summer monsoon.

The predominant livelihoods of the communities involved in the project are agricultural, with both own cultivation and labouring on larger farms, particularly among younger community members, or through the rural employment guarantee (MNREGA)[14] being the mainstays of the village economy. The main exceptions were found in peri-urban villages such as Sanghia, where other professions such as carpentry and masonry were also included. Holding sizes here are markedly smaller– average less than 1 acre with a large holding no more than 6 acres - and more likely to include rented land. The percentage of landless households was also higher (about 10%) and households rely more on vegetable production for the urban market than the main staple crops.

Fish ponds and small poultry units can be combined with ecological agriculture to diversify food security and resilience

Elsewhere, rice (in the summer monsoon) and wheat (as a winter crop) predominates with potato, groundnut, sugar cane and vegetables also grown. In general, holdings average about 1 acre with holdings categorised as large or very large in the 10 – 20 acre range.

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[13] *See* **http://www.geagindia.org/**

[14] The 2005 Mahatma Gandhi National Rural Employment Guarantee Act guarantees 100 day's work on the minimum wage for every household whose adult members volunteer to do unskilled manual work.

Between 85% and 95% (depending on the village) of the 92 farmers that took part in the community discussions were farming less than one acre.

There was a high degree of continuity in the perceptions of changes in climate over the past 5 to 10 years from all villages. Summer temperature and particularly heatwaves are perceived to have increased. While total amounts of rainfall are either not thought to have changed or declined slightly, the rainfall pattern was cited as the most significant change, with the monsoon starting 15 – 30 days later and rainfall less regular, more intense and with longer dry spells in between. Some respondents felt that all seasons had shifted forward and the duration of the winter season had declined. Others added that while summer temperatures were higher, winter temperatures had been lower in recent years. The main spontaneous adaptation measures have been to delay nursery development and transplanting for rice, using earlier maturing varieties for both wheat and rice in order to cope with a shrinking winter season and a later monsoon onset respectively.

Two main features should be highlighted – firstly the high degree of agreement between the perceptions of farmers and the scientific evidence of climate change for Northern India generally, and secondly the pressure that this exerts on agricultural livelihoods. As climate changes increasingly affect production and the cost of inputs rise, farmers are caught in a vice of incremental stress on their livelihoods that can progressively reduce their ability to develop resilience. The ecological alternative to conventional chemical agriculture that GEAG promotes addresses both sides of this equation by reducing chemical input use and therefore cost and increasing resilience, productivity and profitability through sustainable, ecological farming methods.

3.2 Developing and communicating climate services

The focus for climate information services has been on providing a regular, tailored 5 day forecast to farmers across four districts. As well as employing an in-house climatologist, GEAG have established a network of 6 rain gauges and 2 observatories (one automatic) to develop the forecast. To this is added data from a further 7 automatic weather stations and 2 observatories managed by the Indian Meteorological Department (IMD), giving a total of 17 measuring points. Access to IMD information is unlocked through a R5,000 subscription.

Forecasts are developed using a numerical weather prediction (NWP) model on a 9 km grid, and so IMD data that adds to that obtained from the 17 direct measuring points is essential, such as upper wind speed and upper air temperature at 5-24,000 feet above sea level, mean sea level pressure, potential vorticity, convective available potential energy and temperature, and lifting condensation levels. Conventional forecasting methods are combined with the NWP using norms to identify low pressure systems, wind troughs, cyclonic shear circulations, etc. During the monsoon, the location of the axis of the monsoon trough is important in anticipating how and where movement will occur that affects rainfall patterns. This is all interpreted to develop the 5 day forecast.

However, NGOs cannot release forecasts autonomously. This in-house forecast for basic temperature, humidity, rainfall, frost and wind speed is then cross-checked with the IMD, the Ministry of Earth Sciences and the Narendra Deva University of Agriculture and Technology (NDUAT). Through this refining and tailoring process are added specific agro-meteorological recommendations depending on the time of year. For example, farmers near to harvest need wind gusting information as this potentially damages standing crops. During winter months, frost forecasts enable farmers to take mitigating actions to reduce crop damage. Pest outbreak risks, often related to rising temperatures and humidity, are included with advice on which organic method of bio-pesticide use is most appropriate. This, like other agricultural recommendations, can also be used by farmers using chemical inputs but is tailored to ecological farming methods, which are judged as providing superior resilience to climate variation and extremes. If IMD issues a flood warning for the Rapti River basin, this is also added into the forecast.

The automatic weather station (temporarily relocated) being explained by Kailash Pandey, GEAG Climatologist (with the readout, bottom RHS)

Communication of the forecast is primarily through SMS message sent to mobile phone owners registered with the GEAG climatologist. Currently these total 563 farmers in 50 villages, with a further 2,500 receiving the forecasts indirectly (both figures are rising fast). Transmitted in Hindi, the SMS is worded carefully to ensure that it is clear to farmers. Training is also provided through farmer field schools on the forecast meaning and use and monthly reviews are carried out to enable farmers to feed back on the reliability of the forecast, make recommendations for any changes and register new phone numbers for those wishing to join the network. Practical challenges include timeliness of the forecast development and approval process to ensure each is transmitted regularly and on-time. This can be particularly acute during the monsoon when power shortages are more frequent and IMD is under more pressure.

On the demand side, farmers sometimes change their mobile number which creates a gap in transmission until their new contact is registered. The SMS itself can get buried under numerous advertising text messages and so occasionally missed. Illiteracy can also hinder transmission by up to a day as the SMS recipient finds someone to read the message to them. To supplement the SMS method, noticeboards have been established in villages to transcribe the forecast and ensure that all farmers, not just those registered and owning a mobile phone, can access the information. These are situated in central gathering areas and/or near to rural roads or paths so that both residents and people from surrounding areas can easily locate the noticeboard. GEAG's own data shows that both numbers of farmers receiving the forecast and use of recommendations has increased, suggesting both increased demand and usefulness of information.

Fig 10. Growth in number of SMS recipients[15]

	Direct recipients		Indirect recipients	
Year	No. of receiving farmers	% using at least 50% of the recs	No. of receiving farmers	% using at least 50% of the recs
2012	162	44	65	31
2013	350	61	145	55

3.3 User response and livelihood impact

In general, very little other forecast information has been used by farmers receiving the 5 day forecast, either before the project started or subsequently. Most referred to the one day forecast through either TV or All India Radio, but this only gave basic rainfall and temperature data. One group knew about a 2 day forecast in a local newspaper but indicated that this was not used for agricultural decisions. Likewise farmer field schools had included some general discussion about rainfall and temperature prospects for the next 2 years but not beyond this time frame.

Registering new users for the SMS message

Reliability of the forecasts was considered good with a range of 75 to 100%, and with no transmission reliability problems that would seriously undermine access and use. One group explained that they were hesitant for the first 6 months but their initial reservations were overcome with increased awareness and knowledge of how to apply the information. The multiple channels of information and the ability to interact with the forecast providers every month were particularly valued. Groups explained how they received demand for the forecast - forwarding the SMS to a variety of family members and friends in neighbouring

[15] The forecast network and associated activities have been co-funded by a combination of Christian Aid PPA, Rockefeller Foundation and DFID PACS (implemented through Christian Aid) but will rely on PPA support only from 2014.

villages is increasingly common and the notice boards have also generated significant interest both within the village and from those passing through.

In terms of specific decisions that farmers assess as improved through using the 5 day forecast, these tend to be related to timing of operations or improved targeting of inputs, including:

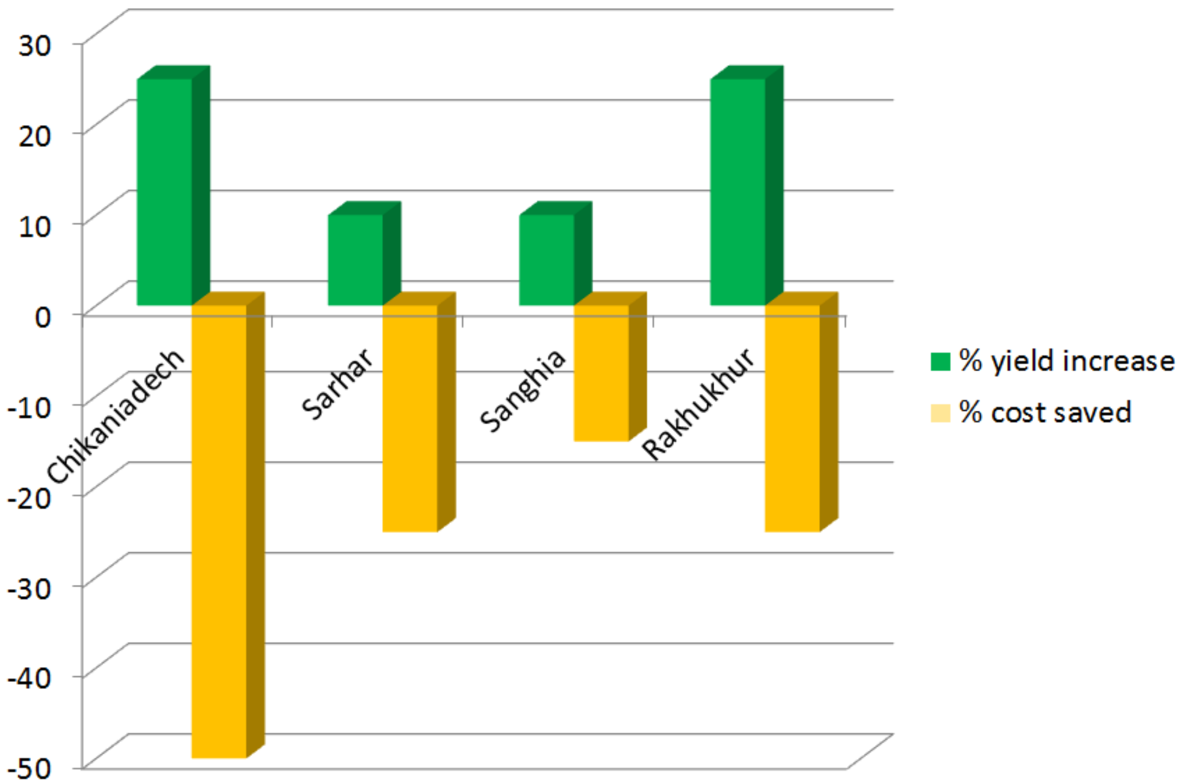
- Adjusting sowing times to cope with later/more variable monsoon onset dates, in particular when to establish rice seedling nurseries and transplant seedlings so that planting can be synchronised with the reliable onset of rain as well as direct planting of e.g. wheat, potatoes.
- Irrigation management – either to avoid unnecessary irrigation (and therefore irrigation costs) prior to rainfall or damaging a crop with excess moisture if irrigation is followed by heavy rain.
- Timing of pest control measures, using humidity and wind speed and direction information to decide bio-pesticide application e.g. applying chilli spray to mustard with an east wind
- Timing of frost damage control using irrigation and smoke to mitigate forecast frost episodes

- Compost/fertiliser application timed to maximise effects on crop growth and yield e.g. avoiding application prior to heavy rainfall to mitigate fertility loss through leaching
- Vegetable nursery development based on temperature forecasts, especially for chillies, onions and seasonal leaf vegetables. This includes timing of operations and management of any potential risks e.g. heavy rainfall affecting the nursery
- Timing the harvest to increase the likelihood of grain being stored at the optimal moisture content, avoiding cloudy weather that would result in higher grain moisture and therefore higher post-harvest losses.

The forecast is posted on notice boards where people congregate, such as markets and shopping areas.

Fig 11. Summary and level of impacts described by farmer groups

Village	Impact
Chikaniadech	Increased crop yields – 70% of farmers agree the effect is positive
	Use forecast to decide whether to work on own farm or go for manual labour
	Avoiding loss e.g. protecting crop from extreme rainfall
	Reducing irrigation, labour and biopesticide costs by 50%
	Specific saving on fertiliser costs for wheat of IR2,400 per acre (about 25%)
Sarhar	Increased crop yields 5-10%
	Avoiding depressed yields through waterlogging e.g. if irrigation is then followed by heavy rain
	Reducing irrigation, labour and biopesticide costs by 25%
	Reduced labour by women especially
Sanghia	Increased crop yields by 10%
	Better fodder conservation improves livestock performance
	Reduced water and labour costs by 15%
	Reduced and/or more efficient use of other inputs also
Rakhukhur	Increased yield through more accurate use of inputs and better timing of planting
	Reducing input costs (mainly labour, irrigation and biopesticides)
	Reducing losses related to damage avoided



In contrast to the farmers in Kenya, the response in discussions about impact tended to focus on costs saved rather than output or yields increased. Farmers referred to a link between changed decisions and increased yields and generally agreed that the impact was in the 10 - 20% range but were much more precise about specific ways that cost savings had reduced irrigation water and labour costs, enabled better timing of pest control measures which were more effective as a result and avoided damage, such as irrigating before a period of significant rain which then damages the crop through waterlogging. Fertiliser costs for farmers still using purchased chemical fertiliser were also reduced, suggesting an improved targeting of these expensive inputs and therefore less environmental damage e.g. through nitrogen contamination leaching into groundwater.

Women respondents also cited a number of decisions about household welfare that forecasts had assisted, including:

- Storing more wood, livestock feed and household goods (including food) if there is a forecast for persistent, heavy rain (over 3 or more days) that will reduce access to local markets and mobility locally e.g. through water-logging.
- Focusing on childcare to mitigate risks of colds and other disease.
- Adjust any travel decisions based on the forecast.
- Take pre-emptive maintenance to avoid e.g. a leaking roof causing problems within the house.

The impact of these improved decisions were described by all communities with an emphasis on cost savings, as a result of either more efficient use of inputs or mitigation of damage to crops, as the most significant reason for use of the forecast.

3.4 Local knowledge and community planning

A number of local indicators were also recognised as useful but these primarily focused on short-term onset of rain, including:

i) Sparrows taking a dust bath indicates rain within 24 hours; taking a water bath means no rain for next 10-15 days
ii) Ants moving their nest indicates rain in the next 2-3 days
iii) Emergence of dragon flies indicates rain in the next 2 days
iv) If wind shifts from a persistent easterly to a westerly, rain will arrive the following day
v) Frogs jumping on the roof means the monsoon is coming

Two villages also described drought indicators which were perceived as very reliable. Bamboo flowering, fruiting and dying indicated severe drought, as did the winter temperatures – warm in mid-January, cold nights in mid-May and heavy first rains from mid-April to mid-May all suggested a drought year. Opinions ranged from viewing these as very reliable so still used to dying out because (especially younger) people were embarrassed to be seen as relying on traditional views of weather and climate.

Communities highlighted the importance of climate services as part of the participatory vulnerability and capacity assessment (PVCA)[16] and action planning process. Initially, those involved in the PVCA were not aware of the various climate services available but the increase in risks associated with climate variation and change – such as waterlogging,

[16] PVCA is a community-based process of analysing the impact of shocks and stresses on the community and, through the action plan, developing activities that mitigate these (especially for those most vulnerable to them) through more effective use of available community resources, local government services and, where possible, external support.

increased crop pests and diseases, livestock and human health – were the most important categories (especially waterlogging) highlighted. Since the action plans were developed, communities have been integrating climate services into their management and implementation in order to increase access e.g. through including registered mobile phone owners on the community map (see below), identifying households that have mobile phones but are not yet registered or including communication methods that ensure those without mobile phones still can receive the information regularly. The monthly review of the forecast to feedback community experience to the suppliers is also part of the action planning process. All communities agreed that the 5 day forecast had been a basis to increase their understanding of climate science and expressed interest in considering other climate services, such as the seasonal forecast, within the same system.

Community map developed as part of the PVCA process, with households receiving the SMS forecast recorded

3.5 Farmer recommendations

Farmers highlighted a number of recommendations with respect to both the forecasting process that they are involved in and the agricultural advice that is combined with the 5-day forecasts:

- Diversifying access to climate services beyond 5 day forecasts in Uttar Pradesh – farmers expressed interest in both the seasonal forecast and understanding longer-term climate impacts. Farmers felt that if a seasonal forecast could assist them plan sowing, transplanting, crop management, etc. across a whole season, this would be useful and would then enable fine tuning through the 5 day forecast, echoing the views of the climate service users in Kenya. Better understanding of the long-term impacts of climate change was also highlighted as important to action plans[17] and to increase understanding of the effective use of forecasts generally.

[17] Developed from the PVCA process

- Integrating rain gauges – these could add value to the forecast users through combining their own data with the forecast. It could also increase their effective application of forecasts.
- All groups asked for more agricultural advice with the five day forecast. The advice they already receive was considered especially useful as it was tailored to sustainable agricultural techniques, but they wanted more detail.
- Better integration of local knowledge – this is still valued and could be included in the forecast e.g. including the behaviour of local indicators on the village notice board forecast. This would enable users to see if they are more, less or equally effective in adding value to a forecast.
- Sustainability is a significant concern for both farmer groups and GEAG – the current system relies on a high level of in-house meteorological skill from the GEAG climatologist with the support of other project staff similarly specialised in agro-ecological agriculture to develop and communicate the forecast and advise and receive feedback from forecast users. A process is needed to present the evidence of the work, especially around the cost-benefit given the strong responses from farmers with respect to both increased production and costs saved. This could also examine how this approach fits with any other forecasting initiatives in Uttar Pradesh and therefore how the essential elements of a system that remains highly useful to and valued by rural communities can be both continued and scaled up to cover demand, potentially across the whole state as well as informing practice in other neighbouring states.

4. Developing Climate Services in Nicaragua

4.1 Intervention area background

Centro Humboldt's approach, in contrast to the focus in Kenya and India, has been to look at climate from both a national and a longer-term perspective. Although overall poverty is decreasing in Nicaragua, inequality means that rising wealth is not necessarily reaching the poorest populations. Forty three percent of Nicaragua's population live in rural areas and 68% of them struggle to survive on little more than $1 per day. In terms of the recurrence, severity and scope of natural hazards, Nicaragua sits within the second most vulnerable region in the world. As well as floods, cyclones and landslides, the country is vulnerable to earthquakes and volcanic eruptions due to its location in the Pacific Ring of Fire. In the western dry corridor, where Christian Aid-supported projects largely take place, droughts are also frequent and cause significant loss of crops, livestock and forestry – meaning food security regularly threatens local livelihoods. Much of Nicaragua's rural population focuses on coffee production[18] as a cash and wage earner. However, these livelihoods are being threatened by the spread of coffee rust, which in 2014 destroyed swathes of coffee plantations.

In terms of recent climate trends[19], average annual temperature has increased at a rate of around 0.2°C per decade, or 0.9°C since 1960, with a similar rate of increase in all seasons. The average number of hot days[20] per year increased by 60, or 16.4%, from 1960 to 2003. This rate has been seen most strongly in June/July/Aug when the average has increased by 6.2 days per month (an additional 20%) over this period. The average number of hot nights per year has increased by 43, an additional 11.7% between 1960 and 2003, a rate seen most strongly is Sept/Oct/Nov with an increase of 5.5 days per month, or 17.6%. The mean annual temperature is projected to increase by 0.6 - 2.7°C by the 2060s, and by 1.2 - 4.5°C by the 2090s. The projected rate of warming is similar in all seasons, but more rapid in the northeast of the country. Days and nights considered 'hot' by current climate standards for their season are projected to occur on 40-97% and 43-95% of days of the season respectively by the 2090s.

Average rainfall has declined by 5-6% per decade since 1960, although the proportion of rainfall falling in heavy events[21] has increased by 2.2% per decade. Likewise the observed maximum 1- and 5-day rainfalls have also shown significantly increasing trends over this period. The annual maximum 1-day rainfall event has increased by 8mm per decade, on average since 1961 and the annual maximum 5-day rainfall event by 14mm. These increasing trends in extremes are seen in both the wet and dry seasons. Future projections of mean annual rainfall do not show a consistent direction of change, but the ensemble median values are consistently negative for all seasons. Projections vary between -63% and +16% by the 2090s, with ensemble median values of -8 to -21%. Percentage changes in rainfall projected show the strongest decreasing signal in June/July/Aug rainfall, the wettest season of the year (-76% to + 11%). Both the likely future proportion of rainfall that falls in heavy events and the maximum 1 and 5 day rainfalls appear to show a decline in future projections, which sharply contradicts the current trend.

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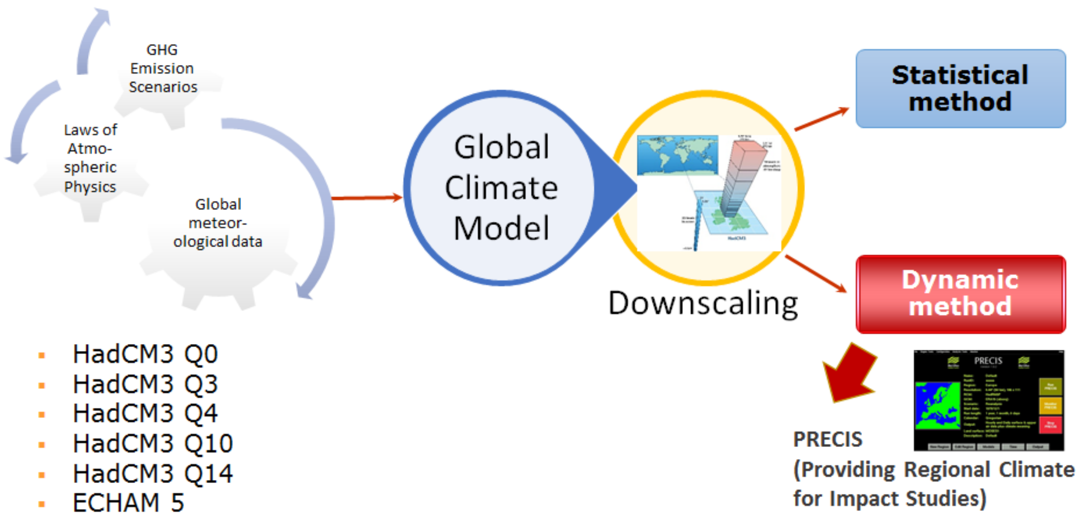
[18] 70% of coffee globally is produced by small-scale farmers.
[19] Data from UNDP Climate Change Profile - Nicaragua
[20] A 'hot' day or 'hot' night is defined as the temperature exceeding the threshold of the 10% of hottest days or nights in the current climate of that region and season.
[21] A 'heavy' rainfall event is defined as a daily/5 day rainfall total which exceeds the threshold of the 5% of wettest rainy days in the current climate of that region and season.

4.2 Developing the regional climate model

Much of the evidence to demonstrate the impact of greenhouse gases on global climate has been derived from the use of global circulation (or climate) models. However, these have generally not operated at sufficient resolution or over the medium-term timescales needed to provide more detailed projections at the regional (or national) levels that can be used for adaptation planning. To address this, regional climate modelling has emerged as a tool to understand the impacts of climate change on both these scales. The main focus of this work is "*to promote knowledge management and technological innovation in the application of dynamic models for small-scale agriculture and to contribute to related national measures to adapt to climate change*".

Fig 12. Regional Climate Model process



Dynamical modelling is generally thought to be a better tool than statistical downscaling as it is based on the laws of physics rather than past statistical associations, which may change as greenhouse gas emissions affect these relationships. The components of climate and climate change interact in a dynamical way and assumptions that are made about these interactions from past behaviour may not necessarily hold in a future atmosphere containing higher levels of greenhouse gases. These emissions will drive multiple changes which interact in dynamic processes. Statistical downscaling also requires more comprehensive climate station data coverage geographically, which is often a constraint in developing countries with limited national meteorology service coverage.

In 2011, Centro Humboldt began work on a climate change project in partnership with other Nicaraguan NGOs Centro Intereclesial de Estudios Teologicos y Sociales (CIEETS) and Nochari[22] to:

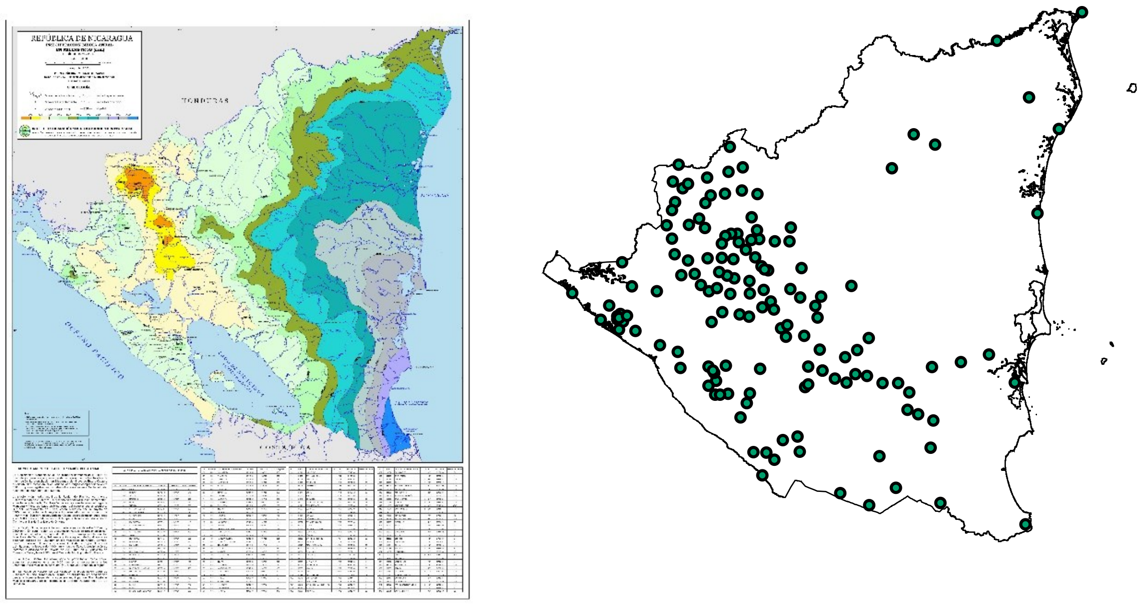
- increase community resilience to reduce risks to climate change, prioritizing adaptation measures in the communities they live to its negative effects.
- increase knowledge management to contribute to understanding of the problems of climate change and finding solutions in a participatory manner with communities and key actors in national life.
- increase advocacy in public policy by consensus proposals from various sectors in a strategic alliance to promote national, regional and global measures.

[22] CIEETS is a Christian Aid partner implementing PVCA, community planning and agricultural development activities in Chinandega; Nochari work on similar issues in Grenada.

Part of this process involved developing a regional climate model (RCM) using the PRECIS computer programme (as per Fig 12 above) developed by the UK Meteorological Office. By combining the climate model with the agronomic requirements of staple crops – maize, beans and rice – an assessment of the likely impacts of climate change on the distribution of areas suitable for their cultivation can be made. Nicaragua has only 128 points of measurement (see Fig 13 below) and 17 full scale climate stations so statistical methods would contain a greater degree of uncertainty. On the other hand, RCMs tend to replicate the biases of their parent global circulation models, so the parent GCM needs to be selected based on the best fit found by running the model for past climates in Nicaragua, in this case HadCM3 Q10, and then calibrating using local meteorological data.

Scenario A1B[23] was selected as the most appropriate emissions scenario and the model resolution was set at 25 km (global models have typically achieved resolutions of around 300 km, although this is changing). Instituto Nicaragüense de Estudios Territoriales (INETER)[24] provided a dataset for the period 1971 – 2000 for calibration but the project also used farmer-generated data over 2 years from 20 rain gauges situated in Chinandega, an area in the dry corridor and known for its drought vulnerability and 7 rain gauges established by communities supported by Nochari in Grenada. Both areas are comparatively lightly covered with formal weather stations, so this added information in these gaps.

Fig 13. Rainfall 1971 – 2000, climate station coverage



The basic modelling process began in early 2012 with an exchange on experience and climate modelling involving staff from Centro Humboldt, INETER and INSMET (from Cuba). This was followed by the development of a database from INETER records for maximum temperature (°C), minimum temperature, average temperature, precipitation (mm/day), relative humidity (%), wind speed (m/s), potential evapotranspiration (mm/day) and sea

[23] The A1B scenario anticipates a balanced direction of technological change in the energy system and sits between A1FI (fossil-fuel intensive) and A1T (renewable intensive), with a context of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The nearest equivalent in IPCC AR5 would be RCP 6.0.

[24] Nicaragua's national hydro-meteorological agency.

level pressure (in Pascal). Training from INSMET on model development completed the process and the development of scenarios at 25 km resolution through data processing and map generation for maize, beans, rice and the Bosawas Biosphere Reserve could commence.

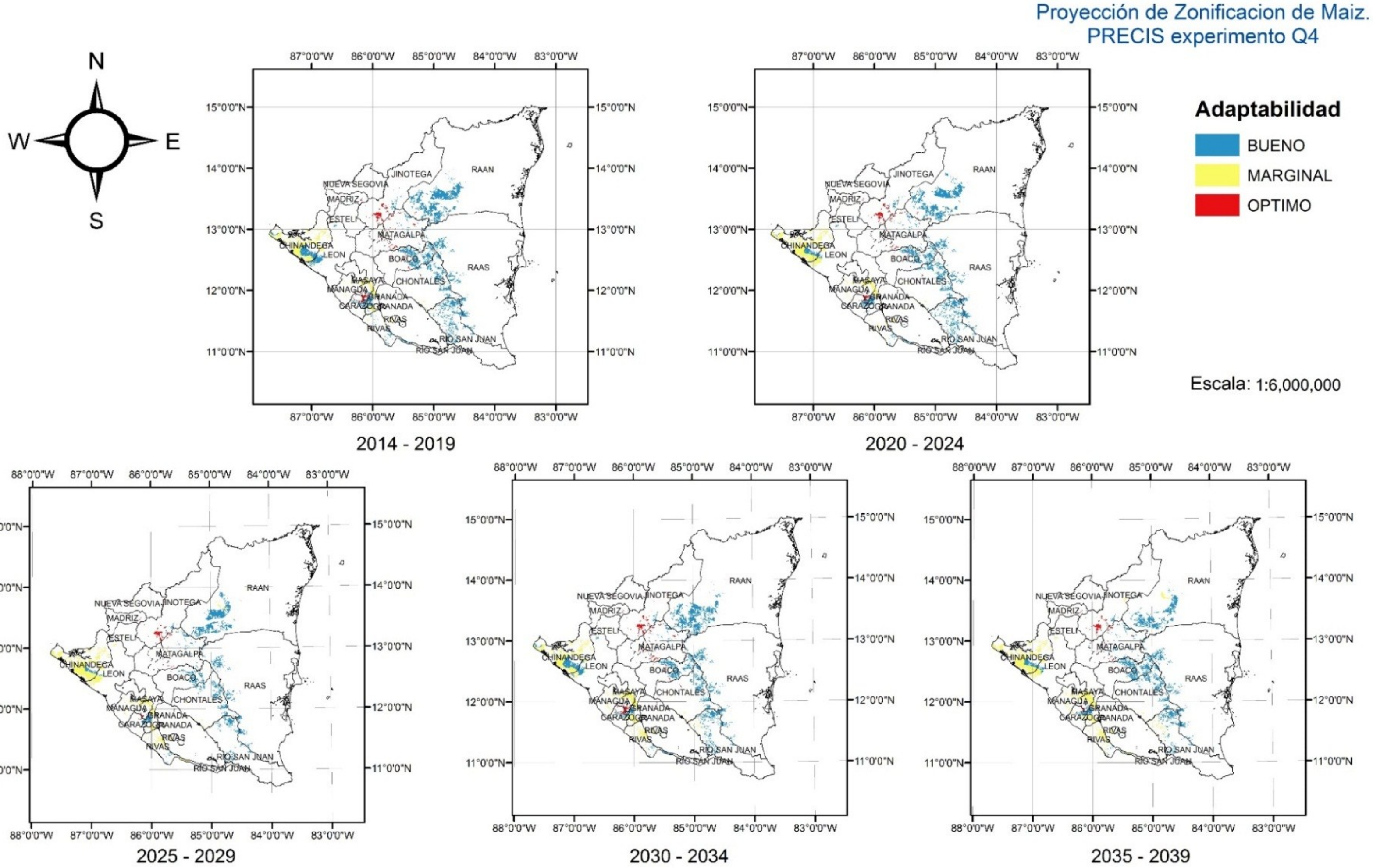
Developing applied scenarios requires some considerable expertise in database manipulation and use of additional software, in this case the relational database management system Microsoft SQL 2012 for data mining and ArcGIS geographical information system to generate maps with graphic output. This combines relevant crop data, such the edaphological characteristics of soils across the country (texture, depth and pH) and the growing conditions required for each crop or crop variety in terms of the climate they need (amount of rainfall, duration of rains, temperature, etc.). So combining the climate derived from the climate model, the crop characteristics and the relevant soil data, a series of maps can be generated that indicates the likely growing regions for the modelled future period. Five scenario periods were selected, each representing a five year interval from 2014-19 through to 2025-39. This therefore downscales climate scenarios to the Nicaraguan situation, fills in the gap between seasonal forecasts and the global models (which generally develop scenarios for 2050 and beyond) and applies it to agricultural livelihood priorities.

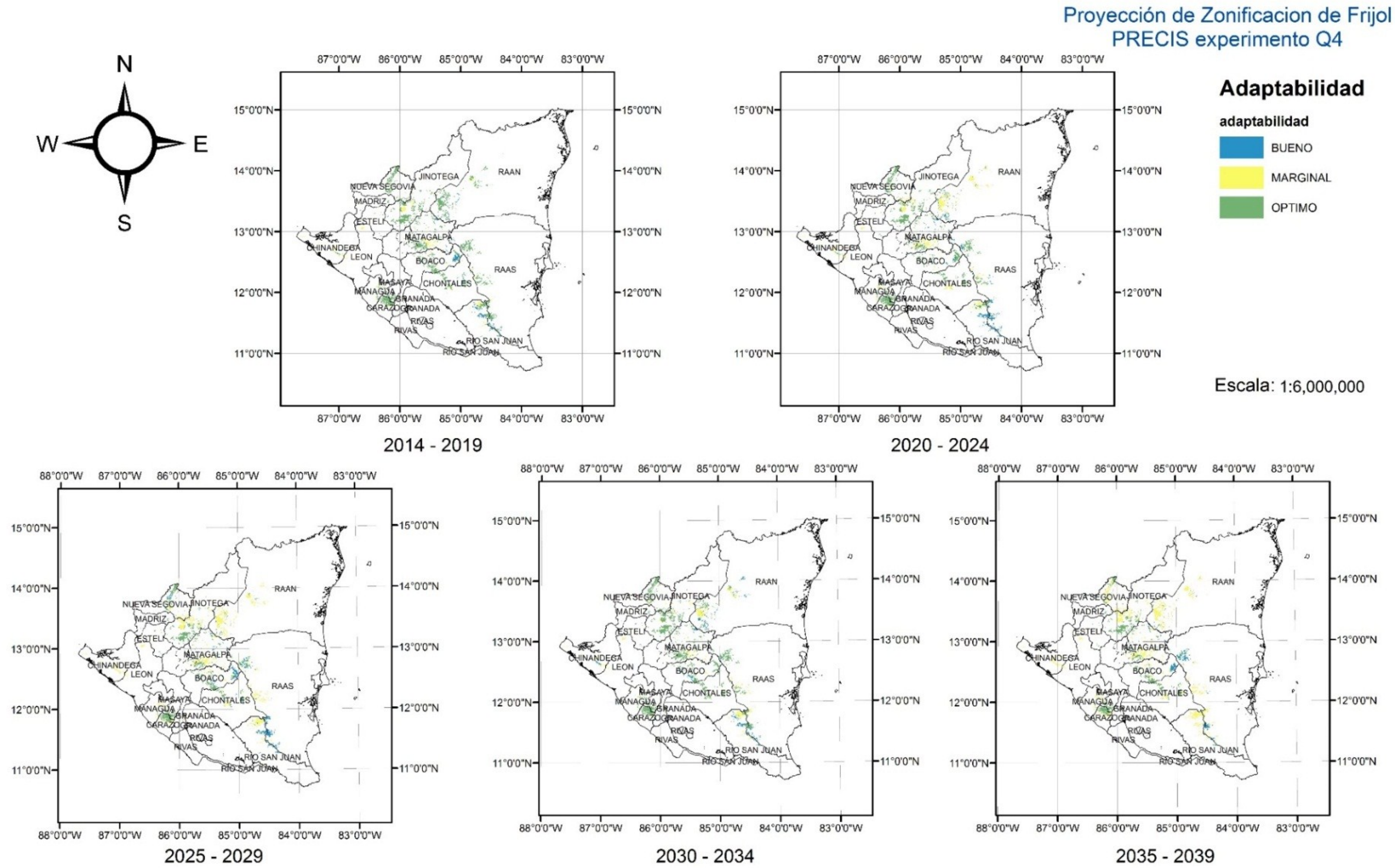
4.3 RCM scenarios – implications and lessons learnt

The maps generated so far show the various scenarios for the three crops – maize, beans and rice - and for the Bosawas Biosphere Reserve. The agricultural scenarios aim to understand how crop areas shrink, expand and/or migrate and are backed with studies in 6 municipalities to assess the actual situation in order to calibrate and validate the scenarios for future refinement. The implications vary but generally show (see Fig 14 below):

- A contraction in the area suitable for maize and beans, in particular the areas considered optimal but also a fragmentation of areas considered suitable. The suitable area in the central highlands will contract and shift eastwards. This then encounters geographical constraints as the agro-ecology changes to lowland rainforest of the western half of the country, which is unsuitable for these two crops. The net effect of climate change is therefore a crop area that is being squeezed between increasing drought pressures (reduced rainfall, increased temperatures) and the restrictions of geography in migrating east.
- This is related to the total rainfall amounts but also the way it is spread across the rainy season (e.g. ideally maize needs 5 mm/day). Different maize varieties have different growing periods, so NB-6 requires 110 days whereas NB-S needs only 100 days. The models show that the first phase of the rainy season – the primera – is likely to become much less reliable in future, merging into the 2nd phase, with consequential need for farmers to switch to shorter season varieties and refine their techniques for planting timing (so highlighting the need for better access to reliable seasonal and short-term forecasting).
- The trend for rice shows some variation from maize and beans with both fragmentation and expansion. Suitable areas in the western side of the country decline but the potential area expands south in the eastern parts. This has implications for rainforest conservation, given its important role in climate regulation and as a source of valuable genetic biodiversity.
- These concerns also have implications for the scenario for the Bosawas Biosphere Reserve (see Fig 15 below), which is perhaps the most dramatic with a rapid expansion of tropical dry forest from 2024 at the expense of tropical rainforest. By 2032-35, this conversion has transformed about 60% of rainforest in this way.

Fig 14. RCM Developed Scenarios for Maize, Beans and Rice




Proyección de Zonificacion de Frijol
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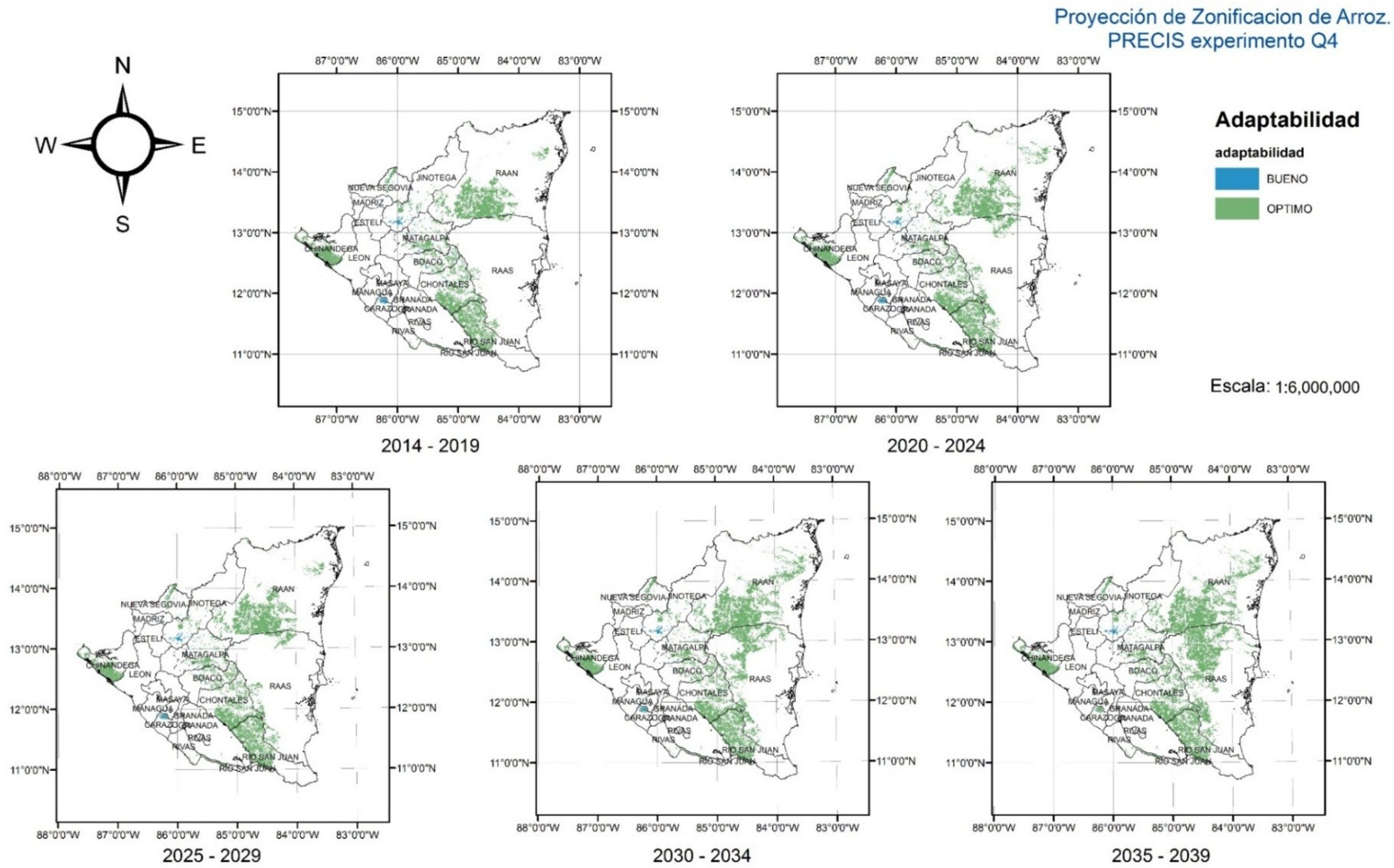
Proyección de Zonificacion de Arroz.
PRECIS experimento Q4
Adaptabilidad
adaptabilidad
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2014 - 2019
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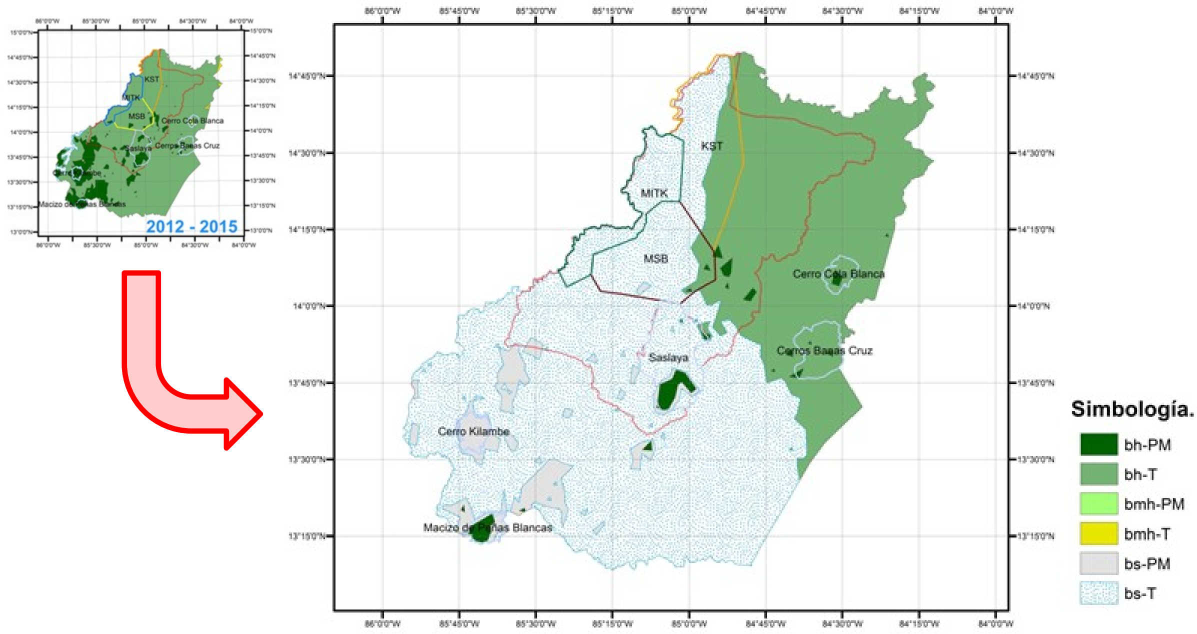
2025 - 2029
2030 - 2034
2035 - 2039
NUEVA SEGOVIA
JINOTEGA
RAAN
MADRIZ
ESTELI
CHINANDEGA
LEON
MATAGALPA
BOACO
RAAS
MASAYA
MANAGUA
CHONTALES
GRANADA
CARAZO
RIVAS
RIO SAN JUAN

Fig 15. The transition from rainforest (solid green) to dry tropical forest (pale green pattern) by 2032-2035



A number of implications emerge from the process, including:

- Feeding the existing crop scenarios into **community planning processes** under the PVCA process. The maps can provide farmers in a given location with both general information on likely future climate change but also more specific guidance e.g. when to plan a shift from a 110 to a 100 day or less maize variety. Matching farmer priorities and plans for production with applied climate scenarios for their main crops can provide important planning guidance e.g. identifying crop and crop variety options to meet future conditions for communities and individual farmers.
- Calibrating using **community-managed rain gauges** in addition to INETER data not only increases the database available for model development but creates a bridge between end user communities and the science that can be used to motivate understanding and facilitate use of model outputs by community planning processes. The involvement of farmer groups in actually generating the model ensures that it is not viewed as external science that may or may not have relevance for them – the sense of ownership and expectation of improved knowledge on longer-term climate change was evident in the community discussions.
- This is **particularly relevant to perennial crops** that have a multi-year development phase before they start yielding and a productive life of several years after this. For example, coffee trees start yielding 3 years after planting and then last for 7/8 years with good management. The scenario for coffee for 2020-2024 has immediate importance for growers currently replanting after the 2013 coffee rust outbreak (itself linked to increased atmospheric temperature, rainfall intensity and moisture levels resulting from climate change). A further refinement of the model could include the conditions for coffee rust (especially moisture, temperature requirements) in order to understand likely future prevalence and persistence of this fungal disease given its relatively recent appearance in parts of Nicaragua previously considered too high to be vulnerable. Scenarios could also be developed for other commodities supported through market chain development (such as cocoa and hibiscus).

- Using the scenarios generated to **feed into the National Adaptation Strategy** and related processes. Nicaragua is an important exporter of agricultural produce regionally, generating 30% of GNP and providing 60% of employment. If staple crop areas are projected to decrease by 40% by 2030 and population projected to double from 7 to 14 million by 2050, this has serious implications for adaptation not just in terms of crop production but the whole food chain. This highlights the need for inter-related sector modelling and mapping as e.g. coffee depends on surrounding protected areas; livestock depends on feed availability.
- Highlighting the **changes needed in national agricultural recommendations**. INTA advice is based on a series of planting guides for various crops but these need to be updated given the likely future climate scenarios. For example, NB-6 is still recommended despite increasingly erratic rainfall in the primera phase, when NB-S or yellow maize would be more resilient.
- Research to better **understand the non-climate change drivers of changing agricultural potential** is also needed, such as overuse of soil, land degradation and deforestation of catchment areas. These risk factors interact with climate risks and increase vulnerability so cannot be isolated from the adaptation process.
- Using the models to **highlight the potential dangers of inappropriate development** – ANACC[25] have already used the data to highlight the environmental hazards that will result from the proposed Chinese-funded canal across Nicaragua and the inappropriate provisions of Law 840, which rides roughshod over a raft of existing legislation designed to protect and promote sustainable use of Lake Nicaragua (the largest freshwater body in Central America) and a variety of forest reserves and protected areas. Potential exists to use this sound scientific basis to highlight the dangers of other unsustainable activities, such as gold mining in Chinandega and the release of mercury into groundwater supplies that will become much scarcer in future climate change scenarios.

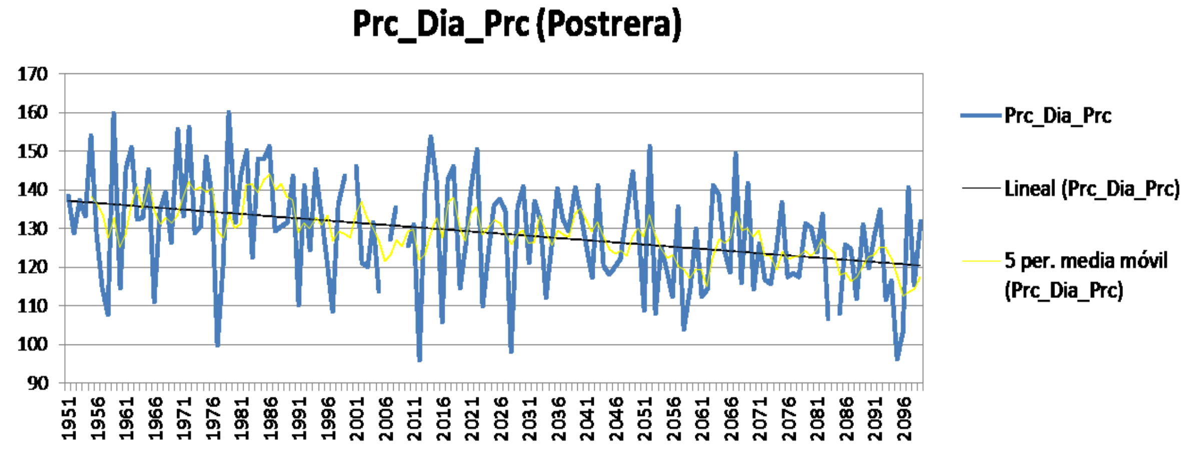
The team developing these important scientific tools emphasised the steep learning curve travelled and the on-the-job learning process that has been required. These included the need for a mixed team of technical and community development expertise to develop model outputs that farmers can relate to, understand and use for decision-making processes. There is also a need to provide technical support to the Municipalities involved, their Food Security and Nutrition Municipal Commission (COMUSAN) members and local Instituto Nicaragüense de Tecnologia Agropecuaria (INTA)[26] staff so that they can use the information to guide their support to agricultural decision making. For both local authorities and communities/farmers, changing their decision-making processes from being based on past experience and data to being based on future climate models is a substantial jump for them and should not be underestimated. This requires a process so that model outputs can be continually compared to actual experience and scenario users involved in further calibration and refinement.

This process is also important in managing the uncertainty that is part of any forecasting. The generation of applied RCMs is a developing discipline that needs constant assessment and updating to improve predictive skill. There is always the potential for 1st order revisions as global models change and improve but the consistency of the scenarios developed with e.g. the projections made in the UNDP country analysis and with other statistical downscaling work (see below Fig 16) increases confidence in their use.

[25] Alianza Nicaragüense ante el Cambio Climático, a civil society advocacy and campaigning network on climate change
[26] The COMUSAN is chaired by the Mayor or Deputy Mayor and including local public sector (including INTA), civil society and community representatives; INTA is the main public sector agricultural research and advisory institution.

Although communities in Matagalpa have not been directly involved in the rain gauge/climate modelling activities carried out by Centro Humboldt in Chinandega, Movimiento Communal Nicaragüense (MCN) has been involved in a statistical downscaling exercise supported by Fundacion para la Investigacion del Clima (FIC)[27]. As with the regional climate model, this has also shown declining rainfall projections for the area.

Fig 16. Rainfall Projection for San Dionisio based on statistical downscaling

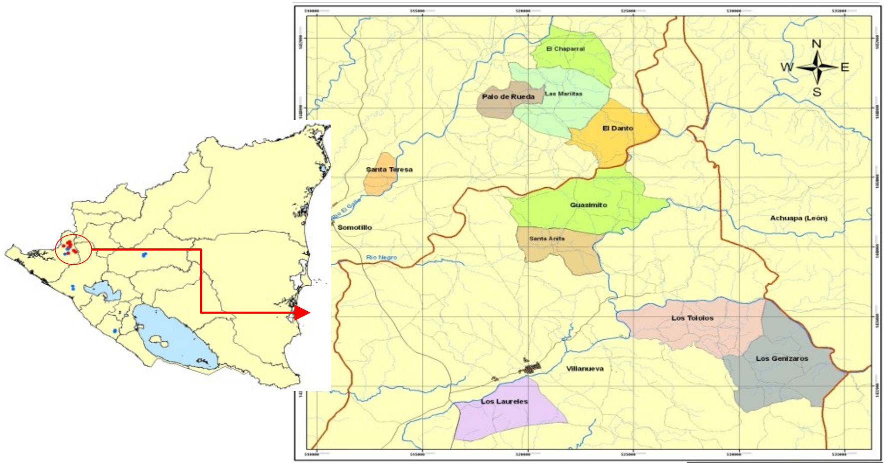


4.4 Community management of rain gauges

Rain gauges have been established in 10 communities across two municipalities for two main purposes:

- To provide additional data that be included in the calibration of the regional climate model
- To enable the communities to collect their own rainfall data in order to inform agricultural decision-making processes

Fig 17. Location of rain gauges



[27] MCN is a Christian Aid partner in Matagalpa; FIC is a Spanish foundation that support the use of statistical downscaling for climate modelling.

Municipality	Community	Area Km²	No. of Households	Population
Somotillo	Santa Teresa	2.66	58	219
	El Chaparral*	7.83	50	383
	Palo Rueda	4.35	68	328
	Las Maritas	12.87	145	725
	El Danto*	13.50	56	300
Villanueva	Los Tololos	16.69	80	1,000
	Genizaros	20.29	110	1,050
	Laureles	11.07	41	297
	Santa Anita	6.90	46	240
	El Guasimito*	18.47	46	322

* representatives present at FGD. For CIEETS-supported communities, representatives of La Careta, San Ramone, La Holota and La Pacaya were interviewed.

A further 10 have been established in communities supported by CIEETS, giving a total of 20 gauges established. Their set-up and management has been guided by the PVCA process which has included training and provision of recording books. Communities have been collecting rainfall records since 2011, recording both daily rainfall and meteorological characteristics, for a variety of local decision-making processes, including:

- Matching rainfall to the phenological characteristics of crops to guide crop management measures
- Using both day-to-day and historical community data to determine the type and variety of crops (maize, beans, sesame, etc.) to plant
- Better estimation of the planting date based on the seed type to be used and the rainfall accumulated
- Early warning of drought conditions e.g. if only 1-5mm is recorded for 3-5 days, planting is restricted and irrigation measures can be used (if available) to reduce moisture stress
- Early warning of flood risks – if greater than 100mm falls in 24 hours, the community is advised of flood possibilities; if greater than 200mm falls, this indicates a high likelihood of local flood risk
- Review harvest prospects based on rainfall records to give an early indication of harvest expectations

as well as to support the RCM development process.

Rain gauge manager showing the recording format used, which combines rainfall data and a descriptive assessment of the day's meteorology

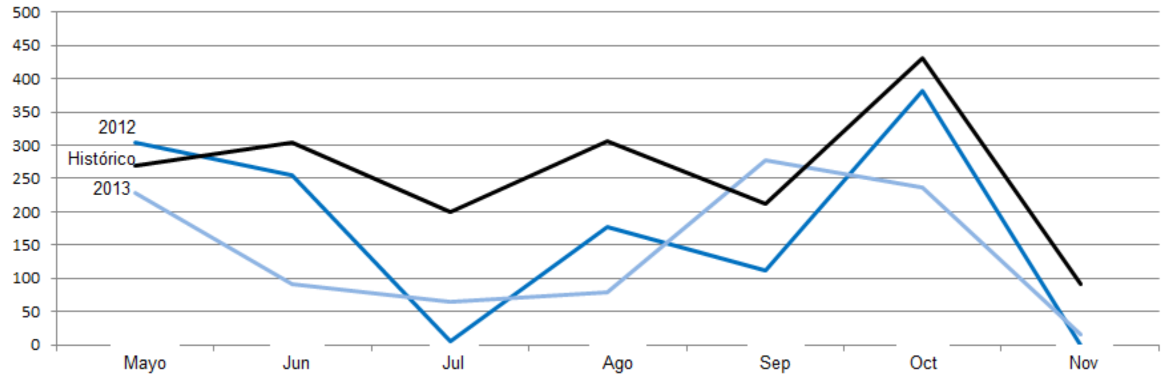
The agricultural season progresses in three phases through the rainy season, with the first crops planted with the onset of rains (the primera) and second and third crops planted as the season progresses. This growing pattern makes rain gauge data particularly useful as farmers need to understand accumulated soil moisture up to three times per season to guide planting decisions. Interestingly, rain gauge data has not just guided crop management but also crossed over into flood and drought early warning. In 2013, in El Dante, farmers knew that 80% of the crop would be affected by drought based on their rain gauge data. This acted as an evidence base on which to approach the Municipality COMUSAN to raise the issue of food security and lobby for drought relief.

Building up a community-managed rainfall database has also supported farmers to adjust their growing season practices to reduce drought risk. This has shown a need to shift the main cropping focus from the primera to the second phase in August after the canicular[28]. However, this also means moving cropping into the part of the season more likely to be affected by hurricane risks and certain pests and diseases that build up as moisture levels increase. So farmers are spreading their options to include some drought resilient cropping e.g. yellow maize to provide some food security in the primera phase followed by a switch to NB-6 in the second phase that is better suited to local soils and rainfall patterns at this stage of the season. Households also are more likely to plant on the same or adjoining days using rain gauge data, a contrast with past practice where households tended to stagger their planting so that each planted on a different day. This makes sense when there is no objective measure to guide planting but with the application of rain gauge information, the need to spread planting days (and therefore planting risk) across the community is less important.

[28] A mid-season dry spell, usually June/July.

Community members and their rain gauge

Figure 18. Community rainfall records vs historical average, El Chaparral



Community members also stressed the need to triangulate rainfall data with other sources of climate forecasting, including their own local indicators. These include:

- the way clouds behave (from the south carry rain, from the north dry),
- tree flowering patterns ("ceiba" tree flowers heavily before good rains), and …
- the pintas/repintas system - if it is cloudy on 1st January, rains will be good early in the season; if it is cloudy on 2nd January, rain will be good in June; a cloudy 3rd January means a wet July and so on up to October. This system is then repeated for the period 7th – 12th January, so a cloudy 1st and 7th January confirms the high likelihood of good early rains in May, the same for the proceeding 5 days. Clear days on the other hand give a warning of dry weather during the respective month of the rainy season).

Although the pintas/repintas system is viewed as the most reliable, local indicators have diminished in use as people depend more on technology. Some farmers felt this was also related to cultural self-esteem (similar to the views of their counterparts in India), leading to a reluctance to discuss local indicators even when they do use them.

Fig 19. Local indicators

Type of indicator	Specific behaviour	Timing	What it forecasts
Early rain	Showers	March/April	Early start to the main rainy season (i.e. May)
Appearance of the sun and/or moon	Halo around	March/April	Early start to the main rainy season (i.e. May)
Chickens	Waking up early	March/April	Early start to the main rainy season (i.e. May)
Ants	Moving nest	March/April	Early start to the main rainy season (i.e. May)
Black and white weaver birds	Nest facing east	March/April	A good season
Cortez tree	Heavy flowering	April	A good season
Ceiba tree	Heavy flowering	April	A good season
Cortez fruit	Goes red quickly	April	A good season
	Goes red slowly	April	A bad season
Monkeys	Urgent calling	During the season	Heavy rain or an earthquake is coming

Seasonal and short-term forecasts are received via radio by most community members but seen as less useful than the locally generated rainfall data and the local indicators, unless providing early warning of impending hurricane risks. Farmers generally viewed forecasts as too general in their description, not sufficiently location specific and not combined with agricultural advice into an agro-meteorological forecast that could be applied to on-farm decisions. There was a general confirmation that establishing rain gauges had improved agricultural decision-making in the 6 ways (detailed above) but farmers were not able to specifically identify any increase in yield that they could attribute to better climate information separately from, for example, switching to a new maize variety (although this in itself may have been motivated by better climate information).

4.5 Nochari increasing yields in Nandaime

In a related activity, since 2010, Nochari have been supporting 14 communities in Nandaime (targeting 400 producer households, 60% women) with a variety of resilience-building measures, initiated through PVCA and community action planning processes. Activities have included establishing a network of 7 rain gauges across the area; agricultural support (training on organic climate-smart agricultural techniques, seed banking, improved access to credit); marketing and advocacy training; and support for dialogue with relevant local authority representatives to deliver on PVCA action plan priorities through resource/budget distribution. As well as providing information to the 14 communities on rainfall which has been used together with farmers' own indicators and local knowledge on climate forecasting, the rain gauges have also fed into the regional climate modelling work of Centro Humboldt, ensuring that both agencies are supporting and can benefit from this process.

In terms of productivity improvements, crop yield data from 400 producers suggests that a combination of (as attributed by farmers):

- increased knowledge and application of organic fertilisers and pesticides,
- better access to seed through seed banks,

- improved agricultural understanding achieved through training provided on what to plant when and
- the application of climate information through use of rain gauges

has had significant impact (see Fig 20 below), improving staple crop yields by 50 – 100% depending on the crop, and an average of nearly 75%.

Fig 20. Yield changes in basic grains[29]

	Yield (mt/ha)				Rainfall in mm	Comments
Year	Rice	Maize	Beans	Wheat		
2010	2.6	1.9	1.2	2.9	1,026	Before the project
2011	2.9	1.7	1.3	2.6	957	
2012	0.3	0.4	0.4	2.6	596	Severe drought experienced, with 50% average rainfall
2013	4.8	3.5	2.3	4.4	1,108	
% incr.	**+83**	**+85**	**+100**	**+50**		**Total incr. in basic grains: +74.5%**

Producers report not just better yields of basic crops but diversification into fruits, vegetables and medicinal plants. This has led to 100% agreeing that they are now eating better or much better (more food, more healthily) and that the health of their families is either better or much better. Moreover, 92% now have food to sell after feeding their families (compared to 37% at baseline), and 98% report improved access to markets since the beginning of the project, with low yields no longer being cited as one of the biggest barriers – all indicators of improved incomes.

Women are increasingly involved in marketing across a range of horticultural products

[29] General PPA Outcome Assessment: Building Resilience in Nicaragua's Dry Corridor - Emily Schechter and Amy Ingham (March 2014)

Only 23% women had access to markets before the project, compared to 89% after. The establishment of a women's network and new income sources, coupled with empowerment activities and training sessions for both men and women, have contributed to the improving status of women, both at family and community level. 98% reported that women have more or much more opportunity to make decisions at both family and community level since the project began. Other impacts include a significant reduction of 88% in those feeling less or much less vulnerable to disasters and climate change since the project began (despite the consensus being that the weather is increasingly unpredictable), and 100% reporting no food scarcity in the last year (compared to only 17% in the 2010 baseline survey who said they never experienced food scarcity during the year).

The project spans a change of local authority officials in 2012 which saw responsiveness to community needs in Nandaime change – reflective of a wider political environment country-wide of closing down opportunities for dialogue. Nevertheless, 65% felt that the local authorities were more or much more responsive to their needs than when the project began. Although no significant policy change was achieved, there were individual cases of success which responded to the priorities expressed by communities within their action plans - including funds allocated to address deforestation and local river contamination, the construction of community irrigation systems, materials to repair damaged houses, electricity installation and the allocation of a space on the local town square for producers to sell their products.

4.6 Farmer recommendations

Community members fed back a variety of recommendations for future action, with the interest in the results of climate modelling work being a uniform feature across all discussions. Having provided rain gauge data, there is understandably a significant level of concern about the prospects for rural livelihoods and an interest in the medium to long-term impacts of climate change for their areas. For coffee-growing areas in Matagalpa, the emergence of coffee rust and its link to increased temperature and atmospheric moisture levels resulting from climate change has increased interest as future scenarios over the next 10 years can support the way growers replant and manage their orchards[30]. In addition to this, a number of other measures were raised:

- The possibility of also monitoring temperature and wind speed records in addition to local rainfall. This was related to both the need to understand temperature as well as rainfall as components of drought risk and wind speeds in relation to storms. Community members also stressed that the need to measure temperature 3 times daily to ensure useful records could be a challenge given their other livelihood activities.
- Much clearer and more understandable daily, weekly and seasonal forecasts via radio, TV and other communication channels. Both more location specificity and the need to combine the technical meteorological information with related agricultural knowledge would help to fill the gap in climate services between the established early warning processes and the imminent discussions on longer-term impacts as revealed by the regional climate modelling exercises.
- Associated issues included the links between climate, forecasts and crop and livestock pests and diseases. As well as coffee rust, poultry and staple crop pest and diseases were highlighted. Secondly the options for moisture conserving agriculture, such as conservation agriculture, and dry season cropping using irrigation.

[30] Coffee exports declined 32% from 2012 to 2013, largely due to coffee leaf rust (WFP, 2014)

Discussions with the Chinandega COMUSAN emphasised the use of local climate data to the development of local food security measures. The existing rain gauge network has demonstrated the importance of feeding this information, and the PVCA action plans themselves, into the development of the 15 year Strategic Plan - local leaders who have been involved in PVCAs are also empowered to approve the Strategic Plan, so this represents a channel through which food security issues raised in community action plans can be incorporated into municipal strategy - as well as more specifically complimenting COMUSAN priorities in early warning of drought risks, increasing access to resilient adaptive technology (crop varieties, irrigation, etc.) and confirming through local rainfall data the need for targeted food aid to areas particularly severely affected by drought or intensive rainfall/flooding. Food security fairs were highlighted as ways to increase awareness of the effectiveness of the approach and promote replication across agro-ecological zones in the area. Interestingly, the COMUSAN echoed the community views on short term to seasonal forecasting and did not use them in their activities to increase local food security. Integrating forecasts on these timescales (as shown in Kenya and India) could add value and deserve further investigation.

Farmers replanting coffee after rust infection could use a longer-term climate scenario to guide this 10 year investment decision

5. Conclusions

Forecast-informed decision changes are strongly perceived to have resulted in increases in productivity by farmers in Kenya and India (as per the impact pathway described in Fig 22 below). Decisions about the timing of on-farm operations (planting, input use), choice of crops and crop varieties and land management have been informed by both types of forecast. Seasonal forecasts tend to inform pre-season decisions that are difficult to reverse, such as which crops to grow, which varieties to use and which soil moisture conservation strategies to adopt. The short-term 5 or 7 day forecasts tend to inform recurrent decision-making for activities such as irrigation use, pest control and soil fertility management.

For small-scale farmers in both countries, short-term and seasonal forecasts have demonstrated their utility to climate resilient decision-making that has in turn resulted in increased crop yields, reduced costs and avoided damage. In India, the emphasis was very much on reduced costs, which may reflect the value of the 5-day forecast in making continuous decisions throughout the season to fine tune operations. The priority given to getting the planting date right in Kenya also suggests a pre-occupation with avoiding the costs associated with erratic rainy season start-up, such as having to replant a crop, but also ensuring that crops make the most of the available growing season and yield well. Farmer responses in India and Kenya suggest that the initial rationale of a 10-20% increase in output is valid and that increasing forecast effectiveness through combining seasonal and 7 day or 5 day forecasts may result in an even stronger impact.

Local or traditional knowledge on climate forecasting is still seen as important in all three projects, although an increased familiarity with and successful application of scientific forecasts suggests that this diminishes as initial scepticism about their relevance and reliability declines. Traditional forecasting methods, even when their scientific basis is thought to be tenuous, are important in several ways – they highlight the climate risks that farmers are pre-occupied with; they illustrate how farmers in any particular context understand the climate around them and they offer an existing and culturally appropriate mechanism for introducing scientific forecast information that climate scientists and intermediaries would be unwise to ignore. Respecting local knowledge also breaks down barriers of reserve that may well exist, given the scepticism farmers expressed about scientific forecasts at the start of all three interventions. Last but not least, some local indicators may well have a scientifically plausible basis to them, as has been demonstrated for the movement and migration patterns of certain bird species.

Confidence in the forecasts used is significantly due to their relative reliability, which in India farmers put at 75-100% and often at the upper end of this range. This raises a cautionary note in Kenya – farmers are provided a deterministic forecast based on a probabilistic set of information. If the forecast turns out to be largely correct, this is not a problem. But if the low probability event occurs, then farmers will perceive the forecast to be “wrong” and as a consequence, their confidence in scientific methods may well decline. The perception that farmers cannot understand the probabilistic figures seems to be well entrenched but giving out deterministic information, albeit as recommendations with qualifications, seems to risk setting up the forecast for a potential failure. If farmers are clear on the probabilities - and they have indicated that if they get the necessary training to successfully interpret the figures, they can be- they can then make the necessary adjustments, using local indicators to supplement where they want to, and take an informed “best bet” decision. Assisting forecast users to manage the uncertainty they contain is an important component of any climate services approach.

The enthusiasm for SMS services through mobile phones is clear, although given the use of multiple channels, it would appear unwise to rely solely on this method. Radio seems to have considerable untapped potential if it can be used to develop much more engaging ways of delivering the forecast other than a dry read-out statement with no complimentary advice or explanation. “Old school” methods, such as direct training and village notice boards also have considerable value. It seems unlikely that there is a “magic bullet” communication technique for any one context and mixed methods designed through a consultation process with forecast producers, intermediaries and users is essential. The strong feedback processes integral to the process in India demonstrated the importance of maintaining two-way communication that strengthens farmer confidence in forecasts. This enables them to manage the uncertainty inherent in forecasting, better understand the science behind the forecast and the link between the forecast, the associated agriculture advice and the decision changes they can therefore consider.

Local specificity in the forecast was a feature that recurred across the three projects – in Kenya, farmers were emphatic on the need for a climate station in Mbeere District and consistently highlighted the 7 day forecast as being relevant because it referred to their district. They also suggested a climate station with a remit rather different from current practice, where stations operate solely as measuring points. Farmers want a local resource that can offer as much advice and support as it can measure climate variables. This “forecasting resource centre” could then offer capacity building for groups on the use of forecasts, managing their own rain gauges (another suggestion), interpreting their own data and generating local information resources for local decision-making. In India, GEAG in effect offers this service which explains the rapidly increasing levels of demand. But it also raises issues of sustainability – who will continue to support these valuable climate services once the project funding ceases? Users, intermediaries, academia and national hydro-meteorological agencies need to work together in designing an agricultural forecasting system that can be sustainably scaled up for all small-scale farmers and pastoralists.

One option frequently raised is to promote private sector solutions. Farmers were generally unconvinced that this would be successful. In Kenya, the “demand-led” approach of incremental privatisation of agricultural advisory services based on the animal health model has simply reduced the number of Government advisors and left a vacuum which local NGOs partially fill. Farmers in all three areas repeatedly expressed their view of climate information as a “public good” that should remain so as it needs to reach the most vulnerable, is important to protecting lives as well as livelihoods (as early warning of floods/ cyclones is provided in both India and Nicaragua with forecasts) and is in fact already paid for through taxes. In India, where some subscription SMS services exist, farmers highlighted the lack of local specificity, the generic agricultural recommendations of limited relevance and the lack of interactivity. Questions were raised on how viable a system would be, as one farmer in the village can subscribe and then distribute it free to other community members if they want it.

In India and Nicaragua, climate services were seen as highly consistent with PVCA-based planning processes, from simple issues such as marking registered SMS forecast receivers on community maps so all know where to get the forecast if they are not yet registered to potentially using longer-term information, such as the results of the regional climate model in Nicaragua, to guide action plan development and implementation. Both the use of PVCA-based planning and the importance of coffee in some parts of Nicaragua may partly explain the interest in long-term scenarios.

The involvement of farmers managing rain gauges has demonstrated the interest and motivation this approach can have for providing advisory services on longer-term climate change. Rain gauges themselves have proved useful to local decision-making on activities ranging from when to plant to the likelihood of impending local flood risks. Together with complimentary support on sustainable, ecological agriculture, this has significantly contributed to increased crop productivity and food security, as shown through Nochari's experience.

As the experiences in Kenya and India show potential for further improving climate services in Nicaragua through exploring the addition of short-term and seasonal forecasts, so the Nicaraguan experience demonstrates the potential for adding farmer-generated science though rain gauges and regional climate model development for Kenya and India. The Kenya Agricultural Research Institute (KARI) in Embu has been involved in a number of initiatives to develop GCM-based crop models that can provide recommendations for 15, 30 and 60 years in the future. These and other potential initiatives, such as using crop models with seasonal forecasts to provide yield expectation support to farmers, could be outscaled to increase the ability of farmers to practice *"response farming"* to increase resilience, environmental sustainability, crop productivity and food security. This also shows that the assumption often stated by policymakers that farmers are not interested in long-term climate information is not borne out by the priorities they expressed in these interventions. Their pre-occupations may be generally more urgent in relation to the approaching rainy season, but they clearly see many investment decisions, such as those related to perennial crops or soil conservation, as potentially enhanced by better information on longer-term climate change.

Another complementarity evident from these three examples is between the use of ecologically-sustainable agricultural methods and climate services. Farmers using these methods tend to value knowledge-intensive ways of building resilience, recognising the damaging effects of chemical inputs to soils, human health and sustainable long-term improvements in productivity and quality of food. While space does not permit a full exposition here on the enhanced resilience to be gained from ecological versus chemically-intensive agriculture, climate services fit well within the ecological approach, which also sequesters more carbon in soils, thereby addressing both the symptoms and the causes of climate change.

Fig 22. The impact pathway for climate services