An Economic Valuation of the Kenya Meteorological Department's Decentralised Provision

Kitui County, Kenya

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February 2016

Keywords:
KMD Decentralised Service, Weather/Climate Information Services, Economic Valuation, Kitui County, Kenya

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Acknowledgements

The authors are grateful for support from Lydia Muithya of Anglican Development Services, and the enumerators and village guides that assisted with data collection; also to Bill Leathes, Joanne Robbins and Ayub Shaka for their comments and suggestions.

This research was funded by Met Office International Development Investment Funding; additional funding to conduct the field survey was provided by the ADA Consortium.

Partner organisations

IIED – ADA Consortium – UK Met

Unpublished report submitted from IIED to the Met Office, February 2016

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Kenya Meteorological Department (KMD) are decentralising services to the county level that offer localised weather and seasonal products with better contextualised design, and more accessible/understandable communication channels relative to national level equivalents. This report uses spatial variation in household income (2014–2015) across Kitui County to model the association between using KMD local level weather and climate products and services and income appreciations. Households receiving KMD decentralised products and services consistently have higher income levels when in receipt of local advisories and seasonal forecasts, and this is compared in relation to those associated with national level forecasts. When benefits are compared to costs, results indicate the KMD decentralised provision is an economically viable investment with comparable returns to similar initiatives within Kenya and other developing countries.

Contents

Summary

Public and private authorities across Africa provide climate information, weather forecasts and early warnings to protect life, property and improve the productivity of sensitive sectors. The challenge is to create reliable, accessible and understandable products and services that meet ever-increasing adaptation needs. In response, the Kenya Meteorological Service (KMD) are decentralising services to the county level that offer localised weather and seasonal products and services with better contextualised design, and more accessible/understandable communication channels relative to the aggregated national level products. This improved provision broadly increases the agency of smallholder farmers, better-informs livelihood planning, and protects from weather-related hazards.

By contextualising products and services, the KMD decentralised provision can generate positive effects for end-users. These include more suitable inter-cropping strategies, land preparation and planting times; pre-emptive livestock management and maintenance; and information also guides households on the viability of different livelihoods and thus facilitates switching between options. All such benefits have an economic value, but the challenge is developing methods that capture such effect(s).

To aggregate benefits for agriculture, pastoralism and other livelihoods, this report uses spatial variation in household income (between September 2014–2015) in Kitui County. The study focuses on the association between the use of local level weather and climate products and services and income appreciations, which are compared to the influence of using national level information as the counterfactual. The analysis builds on the economic valuation literature for Climate Information Services (CIS) in Sub-Saharan Africa by statistically modelling all productive income – farming, pastoral, wage labour, business enterprises and returns on assets – and calculating the independent effect of the KMD decentralised provision as an implemented initiative.

The finding is that households receiving decentralised products and services from KMD consistently have higher income levels when specifically receiving local advisories and seasonal forecasts, and this is in addition to household income levels when in receipt of the national level forecast. Finally, costs and benefits of implementing the KMD decentralised provision are compared over a 10-year period. Costs include not only the County Meteorological Director (CMD) and technical staff, but also other institutions that facilitate dissemination and communication. Results indicate the KMD decentralised provision is an economically viable investment – Net Present Value (NPV) between 11.4m and 58.1m Ksh; Benefit – Cost Ratio (BCR) between 1.11 and 1.60 – with comparable returns to similar initiatives within Kenya and other developing countries.

1. Introduction

Public authorities across Africa provide meteorological services to protect life, property and improve the productivity of sensitive sectors. "Meteorological services consist of the provision of information and advice on the past, present and future state of the atmosphere, including information on temperature, rainfall, wind…as well as the occurrence and impacts of significant weather and climate phenomena such as storms, flooding, droughts, heatwaves and cold waves" (WMO, 2015, p. 2). According to the Intergovernmental Panel on Climate Change, meteorological information (from here on termed 'weather and climate products and services') needs to be reliable, accessible and understandable to meet "pressing and cross-cutting adaptation needs" (Niang et al, 2014, p. 1226). Yet, researchers, practitioners and policy-makers consistently recognise the challenge of making climate and weather information accessible, understood (Kirchhoff et al., 2013), and tailored to the specific requirements of end-users (Unganaia et al., 2013; Grothman and Patt, 2003).

The Kenya Meteorological Department (KMD) is decentralising services to the county level, as part of a broader strategy of devolving government functions across Kenya (KMD, 2014). Headed by County Meteorological Directors (CMD), personnel within County Meteorological Offices (CMO) offer localised weather and seasonal products and services with better contextualised design and more accessible/ understandable communication channels relative to national level products. For instance, national level seasonal forecasts provide three probabilistic tercile rainfall predictions for the country, whilst CMD design local products to differentiate every $10km^2$; likewise, CMDs provide advisories specifically tailored for local flash points, hazards and climate sensitivities at the sub-county level (KMD, 2014a) through communication channels appropriate to each county. Therefore, services address previous deficiencies by: a) supplying information relevant to end-users; b) improving access, comprehension and trust through supplier-end user dialogue; and c) facilitating decision-making and planning capacity (ADA Consortium, 2015).

Weather and climate products and services compliment on-going risk management approaches to adaptation by addressing current climate variability and developing resilience for future climate changes (Watkiss et al., 2014). The KMD decentralised provision aims to improve the agency of smallholder farmers, better-inform livelihood planning and protect from weather-related hazards. Thus, if aims and objectives are met, all such positive consequences have an economic value (Watkiss et al., 2014). For instance, inter-cropping strategies with greater certainty produce higher yields; knowledge of rainfall variation signals the need for provisions to secure livestock and reduce losses; and information on rainy seasons signifies the economic viability of different farm and non-farm livelihood strategies. The multiple uses and benefits of Climate Information Services (CIS) – e.g. improving practices, preparation and making climate-informed livelihood decision-making – aggregate to increase household income via reduced losses when a season is not favourable and positive effects of improved productivity when a season is favourable.

This report uses spatial variation in household income (September 2014–2015 reference period) across Kitui County to develop economic values for the KMD decentralised provision – specifically in relation to local seasonal forecasts and advisories. These values are compared to corresponding income increases associated with receiving the national level forecast. The analysis builds on economic valuation literature for Climate Information Services (CIS) in Sub-Saharan Africa by statistically modelling all productive income – farming, pastoral, wage labour, business enterprises and returns on assets – to establish the independent effect of the KMD decentralised provision as an implemented initiative.

The finding is that households receiving KMD local level advisories and seasonal forecasts consistently have higher income levels, and this increase is in addition to income increases associated with receiving the national level forecast[1] – thus informing about the relative effectiveness and value for money (Watkiss et al., 2014). Finally, costs and benefits of implementing the KMD decentralised provision are compared over a 10-year period. Costs not only include the County Meteorological Director (CMD) and technical staff, but also those of other institutions facilitating dissemination and communication. Results indicate the KMD decentralised provision is an economically viable investment – Net Present Value (NPV) between 11.4m (*£72,152)* and 58.1m Ksh (£367,723); Benefit – Cost-Benefit Ratio (BCR) between 1.11 and 1.60 – with comparable returns to similar initiatives within Kenya and other developing countries.

The document divides as follows: section 2 outlines research into the economic value of CIS; section 3 provides a background and livelihood profile for Kitui County, and specifies value chains for the KMD decentralised provision; section 4 describes the household survey, sampling and model strategy; section 5 documents the economic benefits of the KMD decentralised provision; section 6 costs the KMD decentralised provision; section 7 compares the costs and benefits of implementing the initiative over 10 years; section 8 discusses some implications of the research.

1 No other weather and climate information service providers were active within our sample [KMD are therefore addressing the market failure of private sector under-investment (Watkiss et al., 2014)], despite the presence of Agriculture and Climate Risk Enterprise (ACRE Africa), Regional Centre for Mapping of Resources for Development (RCMRD), Geo Envigro Ltd, Care International, Agriculture Sector Development Support Programme (ASDSP) and Esoko (forthcoming World Bank report). However, the ASDSP do operate as an enabler to develop advisories informed by the KMD decentralised products and services, and a disseminator of them.

2. Past Economic Valuations of CIS

The following section explores literature documenting economic valuations of CIS, outlining studies within developed, developing and newly industrialised states, with particular focus on Sub-Saharan Africa. Approaches establish different forms of benefit valuation – through either modelling techniques, or calculations of willingness to pay – and compare these to the resources necessary to supply products and services. First, the objective is to determine the viability of CIS investments, and second, to facilitate comparison with similar investments options and returns related to broader investment categories within the country.

2.1 Developed States

A large number of valuations for CIS products and services occur within developed states (Fox et al., 1999; Lazo and Chestnut, 2002; Quiroga et al., 2011; Mushtaq et al., 2012; Perrels et al., 2013; WMO, 2015). In terms of modelling techniques: Fox et al. (1999) uses a mean-variance model to estimate the value of forecast methods on wheat production; Quiroga et al. (2011) uses drought information to combine yield response, production losses and insurance costs for different water management systems; Mushtaq et al. (2012) estimate the value of irrigation allocation forecasting using non-linear programming to approximate yield and gross margins from cropping behaviour change. Conversely, in terms of calculating willingness to pay: Anamann et al. (1996) use contingent valuation to value the multiple benefits of the public weather provision in Australia; Perrels et al (2012) assumes more cautious driving, or alternative travel plans as behaviour changes of Finnish drivers – and subtracts losses from an information scenario and uninformed scenario to estimate overall avoided losses; while the Met Office (2007) aggregate avoided losses, lives saved, social/environmental benefits and efficiency.

2.2 Developing and Newly Industrialised States

Studies conducted in developing states primarily focus on avoided losses associated with early warning systems and risk reduction initiatives. Subbiah et al. (2008) develop values for cyclone/flood Early Warning Systems (EWS) across Asia, through transferring qualitative benefits of proactive responses – e.g. movement of assets – into monetary values. Considine et al. (2004) value hurricane forecasts for oil producers operating in the Gulf of Mexico by estimating avoided losses – using unnecessary platform evacuations as the advantageous behavioural change – when forecast accuracy improves. World Bank Group (1996) value a flood protection system in Argentina – with an early warning component – using assumptions of likely avoided damage costs from asset protection. Likewise, White and Rorick (2011) develop economic valuations for disaster risk reduction in Nepal – with early warning again being a sub-component – through assumptions of economic, social and environmental capital saved.

2.3 Sub-Saharan Africa

Within Sub-Saharan Africa, research often concentrates on the qualitative benefits of CIS (Luseno et al., 2003; Vicente-Serrano et al., 2012), due to challenges of data collection capacity. Existing quantitative valuations typically focus on the 'potential' value of CIS by simulating beneficial effects of CIS on behaviour changes in productive practices (Hansen et al., 2009; Sultan et al., 2010; Roudier et al., 2012; Makaudze, 2012). Hansen et al (2009) estimate the potential value of seasonal rainfall forecasts on maize management in Kenya, through combining a stochastic weather model, crop simulation, and enterprise budgeting to establish the value of a perfectly functioning farm and CIS implementation system. Similarly, Sultan et al. (2008) apply a bio-economic model – varying crop simulations with perfect information – to smallholder farming in Senegal. Similarly again, Roudier et al. (2012) use three information scenarios – imperfect tercile forecast, perfect tercile forecast, and perfect tercile forecast with seasonal onset/offset – to simulate crop production and estimate the value of information for millet farmers in Niger.

A growing literature develops values for proposed and actual implementation of CIS in Sub-Saharan Africa, but with robustness challenges. The World Bank Group (2015) transfer findings from a study meteorological infrastructure improvements in Finland, and assume investments make comparable impacts across African countries. Conversely, KMD (2014) develop a direct valuation method using observations of yield improvements – based on changes in agricultural techniques – for farmers using seasonal forecasts. However, it is not clear how controls are incorporated into the analysis to account for alternative explanations of yield increases. Finally, Makaudze (2005) uses contingent valuation techniques to calculate Zimbabwean farmers' willingness to pay for CIS-informed behaviour changes in agricultural practices.

2.4 Economic Valuation of KMD Decentralised Provision

The literature on the economic valuation of CIS in Sub-Saharan Africa is yet to establish a robust valuation of an implemented initiative. Studies into the 'potential' value of information do not account for the complexities and challenges of implementation and uptake; whilst, contingent valuation techniques generate data with reliability issues; and studies documenting values for on-going CIS products and services are yet to account for other influences on the outcome under investigation (e.g. alternative explanations for rising yields).

Many studies focus on improving agricultural yields through weather and climate information induced behavioural changes (Sultan et al., 2010; Roudier et al., 2012; Makaudze, 2012). Yet, this narrow framing is analytically problematic, because such approaches assume climate and weather information only refine agricultural-based livelihoods. Conversely, for pastoralists, behaviour changes brought about by information are not widely documented (for an exception, see Luseno et al., 2003), but interviews suggest influences on livestock management do occur – stocking, splitting, and de-stocking, disease inoculation and fodder management.

The reality in Kitui County in Kenya, and Africa more generally, is that smallholder farmers' sometimes trade-off different livelihood options, including reducing exposure to farming or pastoralism, and instead engaging in non-farm wage labour, business enterprises and other income generating activity. The suggestion here is that substitution between agriculture, pastoralism, agriculture-pastoralism mix, and alternative livelihoods is conceivable when a below normal forecast is given, as this indicates diminishing returns from agriculture, and to a lesser degree, livestock. Therefore, information on weather and climate may influence livelihood diversification strategies themselves, and result in overall reductions in losses, or positive increases in productive income.

To address these characteristics of the CIS literature, this study focuses on variation in household income to simultaneously account for beneficial effects on agriculture/pastoralism, and others relating to an informed interchange across livelihoods. What follows is an ex-post economic valuation of the KMD decentralised provision using income variation for households currently receiving and not receiving local level seasonal forecasts and advisories. The study develops statistical models to test the relationship between KMD decentralised service provision and income levels, whilst accounting for alternative explanations such as asset levels, education and farm size among others. Importantly, the approach facilitates the use of a counterfactual – the income level associated with receiving a national level forecast – that will demonstrate the additional benefit of the KMD decentralised provision.

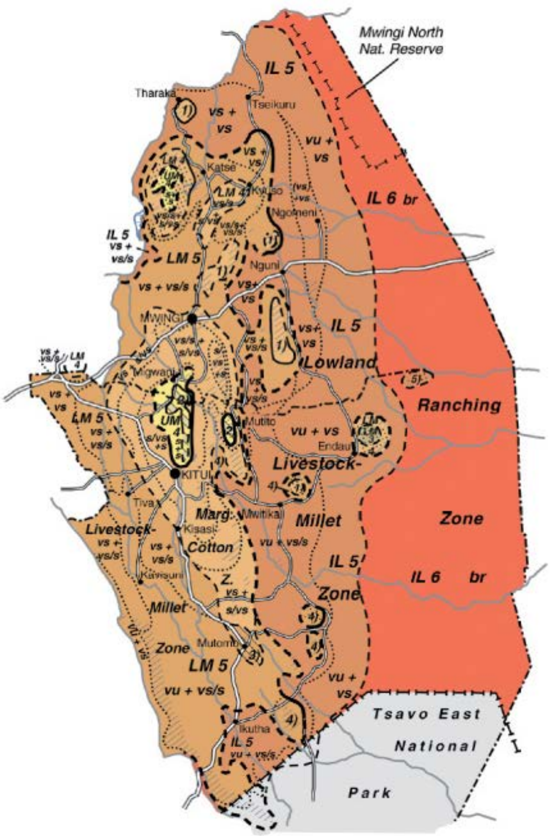
3. Livelihood Profile and KMD Decentralised Provision in Kitui County

Kitui is one of 47 newly devolved county government administrative units in Kenya, composed of 40 sub-county wards. 1.08 million inhabitants reside in semi-arid conditions highly susceptible to drought, due to reliance on rain-fed agriculture and settled pastoralism (CGoK, 2014; Oremo, 2013; Behnke and Muthami, 2011). Such events place pressure on food security and water supplies (Behnke and Muthami, 2011; PDNA, 2012), often inducing circulatory migration, poor health outcomes and compounded poverty (Karanja and Kabulo-Mariara, 2007; Mutimba et al., 2010; Ngigi, 2009).

3.1 Livelihood Profile

Livelihoods in the county are predominantly agro-pastoralist (see Figure 1). The balance between agriculture and pastoralism changes across the county, becoming more agricultural in northern, eastern and central areas where annual rainfall is relatively high (>350mm on average – see Figure 2), and more focused on livestock in the dryer sub-locations of the far south and western areas (<200mm in some areas). Elevation ranges between 400m and 1800m above sea-level (CGoK, 2014), and the higher areas experience more rain more frequently, and therefore lend themselves to agriculture. The most reliable wet season is October, November and December, but significant rainfall is possible in March, April and May.

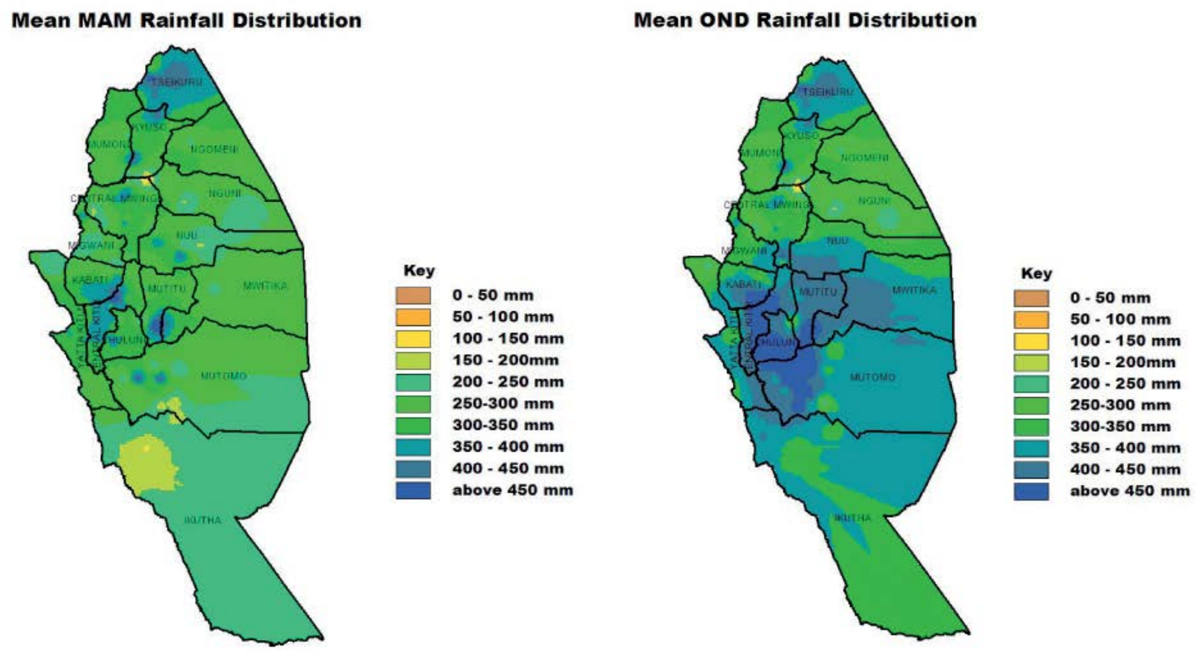
Figure 1: Kitui Livelihood/Agro-Ecological Zones



Source: KMD

The five different agro-ecological zones represent the main variation in livelihoods (see Figure 1). These include: Upper Midland zone (UM4) has sub-humid climate and is regarded as the sunflower, maize and pigeon pea zone; Lower midland zone (LM3) has semi arid climate and is regarded as cotton zone, formed of many steep slopes primarily in forest reserves; while (LM4) is a marginal cotton zone; LM5 and Inner lowland (IL) have arid climates IL5 are the main livestock-millet zones; while LM6 and IL6 are the main ranching zones where little rain-fed agriculture is suitable, except with the use of runoff-catchment techniques. In addition, approximately 44% of residents conduct mixed farming, and 54% engage in marginal mixed farming, with crop farming constituting 25–35% and 20–30% respectively (KFSSG, 2015).

Figure 2: Average Seasonal Rainfall, 1961–1990, March, April, May, October, November, December



Source: County Meteorological Director Kitui (2014)

Intercropping strategies and diversified livestock holdings dominate agro-pastoralism. Farmers often have a preference for maize due, in part, to its palatability among residents. Successful maize production concentrates in the north, west and central areas, but is susceptible to failure. Conversely, drought resistant crops, particularly millet and green grams, are widespread as they endure low rainfall and protracted dry spells (<220mm). Others include cowpeas, beans, pigeon peas, legumes, sorghum, cassava and sweet potato (CGoK, 2014). High rainfall areas (>300mm) can sustain bananas, watermelons and avocadoes, but often form part of a diversified farm. The main industrial crops are cotton and sisal, but very few households have the capacity to engage in such production.

Livestock holdings vary depending on age and wealth distribution, and what follows is based on data collected from a series of focus groups during June 2014 (Speight et al. 2015). Prominent trends include: approximately 2% have oxen/bulls; around 10–15% own donkeys; cows are the most commonly owned large livestock (≈60% of the sample); but the keeping of chickens is more widespread (≈80% of sample); with residents also engaging in bee keeping to varying scales (<10%).

Residents of Kitui also engage in alternative livelihoods. Many have small businesses, including brokerage of crops and livestock produce, labouring for cash on larger farms, making jewellery, handcrafts, garments and leather goods, quarrying and transport services, to name but a few. Many alternative livelihood options require engagement with urban areas within the county – Mwingi, Zombe, Mutomo and Kitui – but a small minority migrate to Thika, Machakos, and Nairobi.

Livelihood choices are subject to various influences. Farmers typically have larger farms than they can plant. As a consequence, they adjust engagement in farming, due to available capital, market prices, rainfall outlook, and availability/benefit of alternative livelihoods. Similarly, scoping data suggest that pastoralists reduce herds based on estimates of pasture availability, and capacity to sustain the herd. Both farming and pastoralism can be reduced, taken over by other family members, and rented for cash. To varying degrees, reductions in farming and/or pastoralism provide opportunities to engage with alternative livelihoods.

3.2 Application of KMD Decentralised Provision to Kitui Livelihoods

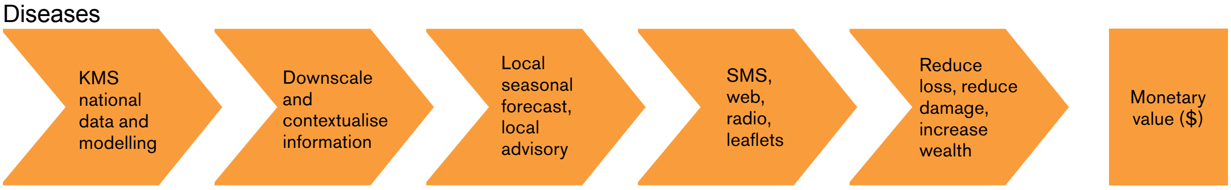
Weather and climate information can offer significant returns to investment compared to other adaptation options. Products and services compliment on-going risk management approaches to adaptation by addressing current climate variability, developing resilience for future climate changes (Watkiss et al., 2014). Watkiss and Savage (2015) state "climate information and services are a key low-regret adaptation option because they support other physical low-regret options addressing the adaptation deficit, such as disaster risk and farm management" (p. 1). Previous work on the value chains for weather and climate products and services show linkages between information and better decision-making (Colvin and Amwata, 2014). Table 1 illustrates how CMOs add value by transforming KMD national level information into contextualised, understandable and actionable products and services suitable to end-user productive requirements:

- First, CMD develop base information using regional-local statistical conversion methodologies, such as FACT-FIT and the Climate Predictability Tool (CPT). FACT-FIT converts probabilistic national level information to predicted local scale rainfall amounts; whilst CPT uses prevailing ocean surface temperatures to infer likely local rainfall conditions using local rain-gauge data for a point specific forecast. Downscaled information is used to produce the local seasonal rainfall forecast (see Column 1), which together with information on season onset/cessation, facilitates risk management in agriculture and pastoralism associated with flooding, rainfall inconsistency, late start/early finishing to the season, and drought. In addition, local seasonal forecasts and advisories indicate appropriate levels of investment in planting and herd size/maintenance. Overall, seasonal rainfall forecast can reduce losses, especially in times of drought, and/or increase productivity when favourable conditions combine with investment (see Table 1).
- Second, CMD work directly with county level ministries within a stakeholder workshop – Participatory Scenario Planning (PSP) workshop/County Climate Outlook Forum (CCOF) –to convert local seasonal forecasts further into ward level advisories based on the geographical, demographic, topographical, and productive characteristics (see Column 1). Advisories demonstrate linkages between rain performance and optimal management of agriculture and livestock within specific wards (KMD, 2014a; 2014b; 2014c). CMD combine technical and local knowledge – using guidance from the Ministry of Agriculture and other sectoral stakeholders in the participatory planning processes – to suggest behavior changes, such as crop varieties, planting times, disease inoculation and other herd maintenance measures.

Table 1: Value Chains – KMD Decentralised Provision – Local Seasonal Forecast, Season Onset/ Cessation and Advisories

(1) Local Product	(2) Beneficiaries	(3) Behaviour Change	(4) Benefit	(5) Possible Valuation
Seasonal Forecast[D,F,RV]	Crop Farmers	• Seed selection • Planting time • Land preparation/ labour • Harvest/storage	• Higher Crop Yields • Increase production • Avoid Crop Losses	• Farmer Income/ Profit • Value of Capital and Labour Redirected • Return on Re-Directed Capital
	AgroPastoralists	• Decide fodder crops • Destock/split herd	• Higher Crop Yields • Avoid Crop/ Livestock Losses	• Farmer Income/ Profit • Value of Capital and Labour Redirected • Livestock Valuation
	Pastoralists	• Animal Movements • Animal Feed Storage • Disease Prevention • Herd Adjustment	• Avoid Herd Losses • Milk Productivity	• Pastoral Income/ Profit • Value of Milk • Value of Improved Herd Condition
Season Onset/ Cessation[ELR]	Crop Farmers	• Planning/ budgetary measures • Land preparation/ water harvest • Hire labour/ sequence planting	• Seeds Germinate • Higher Crop Yields	• Farmer Income • Value of Capital and Labour Redirected
	Agro-Pastoralists	• Destocking/Herd-Splitting	• Maintenance/ Survival of Herd	• Farmer Income/ Profit • Livestock valuation • Value of Capital and Labour Redirected
Advisory[RV,HAD]	• Crop Farmers • Agro-Pastoralists	• Proactive Livelihood Response • Animal Inoculation • Movement of Animals • Drug Provision	• Livestock Saved/ Maintained • Higher Crop Yields • Productive Alternative Livelihood Decision	• Farmer Income • Livestock Valuation • Value of Capital and Labour Redirected

Hazard: RV = Rainfall variability; D = Drought; F = Flood; ELR = Early/Late Rainfall; HAD = Human and Animal Diseases



Once farmers or pastoralists decide to invest in agriculture or pastoralism, information provides a means to optimize output from the chosen activity (see Column 3). Behaviour changes for farmers range from the choice of seeds, to the correct harvest time; and pastoralists are able to manage the size, condition, and regulate the feeding patterns of herds with more certainty. Conversely, past research (Speight et al., 2015) and early scoping exercises in Kitui suggests agro-pastoralists use weather and climate information in more complex ways than simply refining crop production (the common framing of economic valuations of CIS – see Sultan et al., 2010; Roudier et al., 2012; Makaudze, 2012). Smallholders actively substitute between livelihoods – limiting farming and pastoralism and engaging in alternative productive activity – and weather and climate information may influence such decisions, especially when below average rainfall is forecast. To capture the value of these trade-offs requires some account of livelihood portfolios, including income sources and asset (capital) levels (for a list of suggested benefits and potential ways to monetise, see Columns 4 and 5).

4. Data and Methods

This section initially outlines the sampling strategy for data on spatial variation in income levels; the second sub-section details the survey conducted to assess income and collect information on factors explaining income variation; the third sub-section outlines methods used to analyse the impact of weather and climate information on spatial variation in income levels.

4.1 Data Collection

Data collection took place in September 2015 with a survey of 250 households with the assistance of CMO and ADSE representatives. The reference period is the previous 12 months (September 2014–2015) that illustrates the impact of receiving two seasons of local advisories and seasonal forecasts that correctly indicated below normal rainfall; the outcome is income generation and the main method is interviews. September is the end of the productive year, as rains often begin in early October. To maximise the representativeness of the sample, stratified and random techniques were used on three levels:

1. Livelihood zones (see Figure 1). Stratified sampling maximises the inclusion of different production methods and livelihood types, ensuring sampling represents livelihood variation in Kitui, and minimises biases relating to the impact of weather and climate information on particular livelihoods. Five wards were selected according to their placement inside each of the livelihood zones (see the two category rows on Table 2).

Table 2: Livelihood Zones, Wards and Villages

Livelihood Zone	UM4	LM4	LM5	IL5	IL6
Wards	Kyanguithia east	Kyomo/Kyethani	KwaVonza	Ngomeni	Mutha
	Ivaini	Kairungu	Ilika	Ikime	Isaa
	Kaveta**	Karura**	Kanyoonyoo**	Kaalwa**	Kaatene**
	Misewani	Kiomo	Kawongo/Kathome	Kamusiliu	Kalambani,
	Mulundi	Kyethani	Makusya	Kavaani	Kaliakatune
Villages	Museve	Mbondoni	Mikuyuni,	Kavuti	Kengo,
	Mutune**	Wikithuki**	Muvitha/Kathe**	Kimela**	Kiati**
			Ndunguni	Misyi	Kiimani
			Nyaanyaa	Mita	Kiviuni
				Ndatani	Ndakani
					Ngaani

Selected Villages**

2. To ensure a random selection of villages within wards, names are placed in alphabetical order. Every 2nd and 6th village is selected so as that the systematic selection method was unlikely to include corresponding systematic biases (Neumann, 2005). The result is ten villages within five wards.

3. A transect walk method develops a random sample of households that reveals the diversity of village inhabitants (Levy & Lemeshow, 2013). The first stage is to establish the starting point – usually landmarks, such as schools, churches, marketplace, or road intersection. Second, surveyors walk in different directions, and survey every 3rd household. Sometimes populations were sparse and households few, which required reducing the movement to every 2nd to ensure remaining within confines of the village.

The exercise was possible due to prior consultation with village chiefs, and employing village representatives to assist with introductions. Past research raises concerns about the willingness of household members to disclose information on income (Deaton, 1997). Having the consent of village chiefs, and being accompanied by representatives, put respondents at ease. Surveyors sometimes suspected the account of income and other factors was inaccurate – either through lack of understanding of the farm activity, or more deliberate withholding of information. In such cases the survey was withdrawn from the sample (1–2% of households).

4.2 Survey

This section outlines details of the survey: the first sub-section describes the process of household income accounting; the second sets out the variables for weather and climate information, and a range of alternative explanatory factors to model household income; the third discusses some potential measurement problems and how these are addressed.

4.2.1 Household Income

Household income is a complex system. An empirically persuasive account needs values for all income sources, and from all members present within the 12-month reference period [for a discussion on reference periods, see Deaton (1997)]. To categorise income sources, the study uses the Matsumoto et al (2005) and KIHBS (2005) method for framing farm income sources as crops, livestock, non-farm labour, business enterprises, external payments and returns on assets (see Table 3). For the income accountancy framework, see Appendix A.

Table 3: Household Income Summary Statistics

Income Type	Obs.	Mean (Ksh)	Std. Dev.	Min (Ksh)	Max (Ksh)
Farming	250	18,629	39,042	0	363,000
Livestock	250	26,555	47,772	0	250,000
Nonfarm wage	250	46,768	102,716	0	720,000
Business	250	27,001	62,138	0	545,000
External payments	250	19,188	36,672	0	300,000
Returns on assets	250	5,728.8	38,167	0	504,000
Total productive*	250	124,382	168,718	0	1,104,000
Total	250	143,571	173,131	3,700	1,204,000

*Excludes external payments

Several contextual issues arose that required elaboration: accounting for food that families consume is highly problematic, so the focus is surplus produce sold in markets; clear demarcations are also needed to classify non-farm wage labour from business enterprises; and definitions of household residents (i.e. people residing in the house for more than 6 of the last 12 months) are necessary to differentiate between income sources and non-farm wage labour/business enterprises, and remittances sent from family members that sometimes reside outside. As such, standardisation is key, and enumerators spent time before data collection conducting trials and debating definitions/classifications.

4.2.2 Determinants of Household Income

The objective is to establish a benefit valuation for the KMD decentralised provision, and the approach is designed to record and control for the effects of weather and climate information. Respondents provide information on whether they received no information, national level seasonal forecast, local level seasonal forecast or local advisories in the past 12 months. To be classified as recipients, households must receive information from an official source – radio, leaflets, chief's barazas, and extension workers among others. See Table 4 for summary statistics of the relationship between income and weather and climate information. While income increases are apparent for recipients of the KMD decentralised provision, the correlation between the use of the decentralised provision and income may be associated with a range of physical, capacity or demographic factors (see Table 5). Therefore, controls for household capacity and existing assets are crucial.

Table 4: Summary Statistics – Seasonal Forecasts (SF) and Advisory (Ad.)

Income Type	No Inform.	All Inform.	No Nat. SF	Nat. SF	No Local SF	Local SF	No Local Ad.	Local Ad.
				Annual Mean Income Ksh (Obs.)				
Farm	9,391 (21)	**19,477** **(229)**	24,178 (87)	**15,668** **(163)**	16,359 (184)	**24,960** **(66)**	15,563 (169)	**25,027** **(81)**
Livestock	19,095 (21)	**27,239** **(229)**	22,546 (87)	**28,695** **(163)**	25,564 (184)	**29,319** **(66)**	19,787 (169)	**40,676** **(81)**
Non-Farm Labour	20,072 (21)	**49,216** **(229)**	52,054 (87)	**43,947** **(163)**	48,724 (184)	**41,316** **(66)**	41,501 (169)	**57,756** **(81)**
Business	10,776 (21)	**28,489** **(229)**	25,128 (87)	**28,001** **(163)**	23,962 (184)	**35,473** **(66)**	20,876 (169)	**39,781** **(81)**
Production Related	61,421 (21)	**130,156** **(229)**	128,952 (87)	**121,943** **(163)**	121,763 (184)	**131,684** **(66)**	100,637 (169)	**173,925** **(81)**
Total	74,234 (21)	**149,929** **(229)**	141,996 (87)	**144,411** **(163)**	139,624 (184)	**154,574** **(66)**	120,354 (169)	**192,011** **(81)**

Controls include other factors explaining income (see Table 5). Respondents suggest the determinants of income are physical factors such as soil type/fertility [also recognised by Wantchekon and Stanig (2015)] and rainfall [also see Yamano and Kijima (2010)]. Further, literature on household income in Sub-Saharan Africa suggests others including: road quality and distance to markets (Matsumoto et al., 2006); *farm size (Jayne* et al., 2003); education (Matsumoto et al., 2006); number of adults (Yamano & Kijima, 2010); gender dynamics (Matsumoto et al., 2006); and assets valuations (Matsumoto et al., 2006). As a consequence, the survey asks household members about factors within existing models for household income.

Table 5: Determinants of Household Income

Farming Pastoralism	Demographic Controls	Physical Controls
• Farm Size	• Male/Female Household Head	• Location
• Farm Rented/Owned	• No. Adult Women/Men	• Rainfall
• Farm Asset Value	• No. of Children	• Road Quality
• Livestock Value	• Age	• Distance to Market
• Access to Credit	• Education	• Soil Type/Fertility
• Irrigation		
• Fertiliser		

4.2.3 Counterfactual

KMD provide a national level rainfall forecast for the whole of Kenya, on timescales from days to months to seasons, and with varying levels of spatial information. This is the counterfactual for this study – the main alternative source of weather and climate information available. The national seasonal forecast is a tercile probabilistic indication typically providing two or three different rainfall levels/ distribution predictions for the country as the upcoming rainy season approaches. An advisory leaflet providing national level recommendations of particular sectors is available online, but smallholder farmers often receive the national forecast from radio stations. Data was also collected from households receiving no information, and these were used as the reference category, or baseline, in the statistical model (see 'Ref' on Table 6) to be compared with households receiving national and local level information – thus facilitating comparison of additional income associated with the two information sources.

4.2.4 Potential Measurement Problems

Measuring household income is challenging (Deaton, 1997; Pettersson, 2005) despite being a widespread practice across developing countries (Fiedler et al., 2008) and Kenya more specifically (KIHBS, 2005; APHRC, 2014). Surveys require careful attention to gather all income from all household members. This is particularly important for income from assets, sales of food, and accounting for consumption of on-farm produce. Many issues are addressed in the sequencing and structuring of the survey, or by using the accounting framework demonstrating interactions between income sources (Deaton, 1997). Others include accounting for problems and biases in reporting consumption of on-farm produce, and so the survey focuses on surplus income made through the sale of produce not consumed.

Household income surveys are often subject to under-estimation biases (Pettersson, 2005; Deaton, 1997). However, this is less of a problem when developing an economic valuation of weather and climate information products and services. Income levels themselves are not the main finding, but rather the value associated with these products and services. Indeed, assuming the bias is systemic across the sample, such a bias adds weight to any measurable positive effect by possibly being an underestimation.

A greater concern is that particular households assume data collection is conducted for taxation purposes (Petterson, 2005), or other reasons with punitive consequences, which will likely result in random underestimation (Deaton, 1997). In response, each household survey was conducted with consent of village chiefs, and each interview was held in Kamba – the local language in Kitui – with known community members and trained enumerators (see Section 4.1). Each interview began with an extensive introduction outlining the purpose of data collection. For the majority of households, these provisions were enough to secure trust.

4.3 Data Analysis Methods

The analysis is conducted using regression statistical techniques [for overview of methods to measure information effectiveness, see Gasc et al. 2014)]. Since income is unlikely to fall below zero, the dependent variable is classified as 'censored'. Regression options for this type of dependent variable include the Tobit regression with lower level censoring [for random effects application to household income, see Yamano and Kijima (2010); for the same model without consideration of the censored dependent variable, see Matsumoto et al. (2006)] and negative binomial models. Tobit regression can also function well with distributions of monetary counts (Alesina and Weder, 2002; Berthelemy, 2006), meaning that independent variables have an equal impact on the probability of a specific income stream being zero as they do for the amounts when income is positive. However, this model is perhaps suited to situations when censoring is a consistent feature in the variation – e.g. when a proportion of entries are zero – which is not the case when focusing on household productive income.

Household income streams are monetary counts with characteristic distributions. Thus an alternative is to use count models. Poisson regression provides the log outcome as a linear function of the set of explanatory factors and allows for a significant number of zeros; such a feature is important for modelling individual income streams, such as farming or business enterprises. Yet income data violate the Poisson 'over-dispersion' assumption, as for the majority of cases, the variance exceeds the mean. This requires a Poisson extension model, such as negative binomial regression, allowing the same mean structure as Poisson regression but with an additional parameter to model over-dispersion.

Spatial clustering controls address unobserved factors intrinsic to villages, and is a standard procedure when using such units. On the assumption weather and climate products and services have statistically significant effects, post-estimation techniques show the marginal impact of products and services on income. Marginal effects facilitate comparison between household income with a national level seasonal forecast and income with local level products and services, and demonstrate additional benefits of the KMD decentralised provision.

5. Economic Valuation of KMD Decentralised Provision

The following section documents the economic benefits of the KMD decentralised provision: the first sub-section presents and discusses the household income model, and develops marginal effects on the household income for each form of weather and climate information; the second sub-section, up-scales the economic benefits of the KMD decentralised provision across Kitui.

5.1 Household Income Models

Household income models (see Table 6) use 'non-correlated' (independent and distinct factors that explain income) determinants of productive income; multiple iterations of the income model are possible but all include measures of farming/pastoralism capacity, demography and physical factors. These 'non correlated' factors establish the strength of relationships between income and weather/climate information, whilst simultaneously providing different 'control' scenarios (i.e. Models A-E demonstrate different combinations of controls). A control scenario is designed to represent alternative situations, such as income being determined by CIS, livestock assets and demography where different household demography measures are tested. In addition, all models present the full range of weather and climate information as single categorical predictor variables (called categories 1–6 in Table 6); these account for household income differences associated with different categories of weather and climate information relative to households that receive no information (i.e. the reference category).

Relative to the reference category (no information), Table 6 suggests there are consistent statistically significant appreciations in productive income for those households receiving the national level seasonal forecast (category 1), the local seasonal forecast (category 4), local level advisories (category 6), and local seasonal forecast and advisory combined (category 5). Households in receipt of either national or local level forecasts/advisories are associated with higher incomes than those with no information, but the precise extent of the increase is investigated below to facilitate comparison between the two categories (see Table 7). Crucially, the information-based explanations exist alongside the more typical indicators of income increases, such as: the value of land [related to farm size (correlated by 0.33)], and average value of livestock [related to farm assets (correlated by 0.37)]; distance to the local market (other location-specific effects are accounted for by clustering the model on village names); capacity related factors such as the use of on-farm irrigation [education levels are accounted for via the correlation (0.59) with the number of adult men]; and demographic factors such as number of children and adult men within the household, and whether households are male-headed. Farm-related asset and capacity variables show the strongest relationships, and the results for demographic factors are statistically insignificant alongside such factors.

Table 6: Household income models across Kitui. Dependent variable is total productive income; p-values in parentheses; Models A-E use negative binomial analysis clustered on 10 villages, with each model offering a different combination of controlling factors

Information categories	Model A	Model B	Model C	Model D	Model E
(0) No Information	(Ref)	(Ref)	(Ref)	(Ref)	(Ref)
(1) Nat. SF	0.544* (0.07)	0.531* (0.07)	0.538* (0.06)	0.543* (0.07)	0.540* (0.06)
(2) Nat. + Loc. SF	0.326 (0.30)	0.299 (0.338)	0.306 (0.319)	0.323 (0.308)	0.312 (0.30)
(3) Nat. SF + Loc. Adv	0.563* (0.09)	0.551* (0.08)	0.555* (0.09)	0.556* (0.10)	0.557* (0.08)
(4) Loc. SF	0.478** (0.02)	0.461** (0.02)	0.467** (0.02)	0.569** (0.02)	0.469*** (0.01)
(5) Loc. SF + Loc. Adv.	0.578* (0.10)	0.539* (0.10)	0.540* (0.09)	0.569* (0.10)	0.542* (0.08)
(6) Loc. Adv	0.552* (0.06)	0.545* (0.07)	0.559* (0.06)	0.559* (0.06)	0.562* (0.05)
Control Variables					
Value_Land	2.490** (0.03)	2.246* (0.06)	2.134* (0.07)	2.451** (0.03)	2.073* (0.09)
Value_Livestock	1.650*** (0.00)	1.764*** (0.00)	1.758*** (0.00)	1.636*** (0.00)	1.755*** (0.00)
Distance_Market			-0.005 (0.41)		-0.005 (0.41)
Irrigation	0.752*** (0.00)	0.787** (0.00)	0.770*** (0.01)	0.755*** (0.01)	0.761*** (0.01)
Number_Children	-0.008 (0.78)			-0.007 (0.80)	-0.007 (0.80)
Male_Headed	0.016 (0.41)	0.161 (0.38)	0.163 (0.36)	0.164 (0.41)	0.172 (0.38)
Number_Adult_Men			0.033 (0.58)	0.027 (0.00)	0.032 (0.61)
Household_Pop		0.120 (0.56)			
Constant	10.588*** (0.00)	10.588*** (0.00)	10.280*** (0.00)	10.554*** (0.00)	10.620*** (0.00)
N	250	250	250	250	250
No. Groups	10	10	10	10	10

***p < .01, **p < .05, *p < .1

Box 1: Examples of Non-Recipients, and Recipients of National Seasonal Forecast and Local Advisories

Household Ndolo receives no information and makes the same plans to farming and pastoralism as previous years. As the rainfall in 2014–2015 was below normal, Household Ndolo incurs reduced yields from crops, lost livestock, and missed income-generating opportunities on account of the significant investment in farming and pastoralism. **Household Kimanzi** receives a below normal national seasonal forecast and decides to plant drought resistance crops, but does not change behaviour in relation to livestock, or substitute engagement in agricultural/pastoralism for an alternative livelihood. Household Kimanzi manages to produce enough crops to bring to market, though still loses part of the herd to dry conditions, and fails to capitalize on other income sources. **Household Malombe** receives and follows a local advisory informed by the local seasonal forecast that recommends specific crop types, and suggests inoculation for certain livestock. Household Malombe understands the yield limitations of the crops recommended, scales back farming, and switches to non-farm wage labour to supplement incomes. Actions taken as a result of the advisory result in reduced losses from farming, maintenance of the herd, and alternative income streams, which together operate as a comprehensive strategy to manage climate risk.

To establish the productive income values for different categories of weather and climate information in Models A-E, a marginal effects post-estimation technique holds other explanatory factors at their mean (see Table 7 for the comparable national and local categories – excludes households that simultaneously receive both national and local products and services). The model predicts that receiving a national level seasonal forecast is associated with a mean income level between 113,997Ksh (£721) and 114,201Ksh (£722). This constitutes the baseline or counterfactual, as it represents the weather and climate information available in the absence of the KMD decentralised provision. The differences in mean income levels for those receiving local level products and services are as follows: local level seasonal forecast recipients have a mean income level from 106,293Ksh (£672) to 107,644Ksh (£681), and thus provide no addition benefit when compared the national level forecast; local level advisories are related to income levels between 114,359Ksh (£723) and 117,130Ksh (£744), and when taken as an average provide an additional 1,845Ksh (£11.68) compared to the national level forecast; and both local services combined are associated with incomes levels between 114,359Ksh (£723) and 117,130Ksh (£741), and when taken as an average offers 1,499Ksh (£9.49) more than the national level forecast.

Table 7: Marginal Effects of Weather and Climate Information on Annual Household Income (Ksh)

Information categories	Model A	Model B	Model C	Model D	Model E	Mean Value	Additional Benefit
(1) Nat. SF	114,014***	113,997***	114,201***	114,077***	114,096***	114,077	–
(4) Loc. SF	107,644***	106,382***	106,293***	107,634***	106,345***	106,859	–
(5) Loc. SF + Loc. Adv.	117,130***	114,961***	114,387***	117,047***	114,359***	115,576	**1,499**
(6) Loc. Adv	114,877***	115,647***	116,579***	115,857***	116,654***	115,922	**1,845**

****p < .01, **p < .05, *p < .1*

The final stage of the economic valuation is to extrapolate the findings across Kitui. Table 8 sets out in the first 3 columns the likely number of rural households, the proportion of households receiving local advisories alone, and in combination with the local seasonal forecast, and then the probable number of households receiving these products and services. The scenario accounting for 100% of the benefits provides 26.4 million Ksh (£167,544) per annum. Though it is possible that coverage lessens in particularly remote areas, and so two other scenarios assume products and services reach only 70% and 85% of recipients, and in which case, benefits reduce to 18.5 million Ksh (£117,281) and 22.5 million Ksh (£142,469) respectively.

Table 9: Costs of KMD Decentralised Provision including Dissemination/Communication Assistance

	Kitui Rural Households	Proportion Recipients	Kitui Recipients	Benefit 70% Recipients	Benefit 85% Recipients	Benefit 100% Recipients
Loc. SF + Loc. Adv.	118,613*	4%**	4,744	4,977,879	6,044,567	7,111,256
Loc. Adv.	118,613*	8.8%**	10,437	13,552,444	16,686,039	19,360,635
Total Benefits				**18,530,323**	**22,501,107**	**26,471,891**

* Calculated by dividing the rural population (793,764) by the average household population (6.692)
** Using the proportion of recipients within the sample

6. Costs of KMD Decentralised Provision

The cost of the KMD decentralised provision are additional to the national level forecast, as the CMD and supporting staff operate a 'switching station', converting/combining existing national level information with local information to produce the local seasonal forecast and advisory. What follows costs all aspects of service delivery – from data collection to communication – made possible by engagement with the CMO, ADS and their associates.

The costs of providing the KMD decentralised provision relate to premises, personnel, transportation, data collection, communication, dissemination, and operational equipment. These breakdown as follows: a new premises houses the department at 12.1 million Ksh (£76,582); core staff include the CMD, three technicians and a communications officer at 4.18 million Ksh per annum (£26,455); a new vehicle [2.58 million Ksh (£16,329) in year 1] that requires on-going maintenance and fuel [80k Ksh (£506) per annum], along with additional data collection transportation costs and rain gauge maintenance costs for technicians [512k Ksh (£3,240) per annum]; communication requires internet connections [184k Ksh (£1,164) per annum]; training and competency review workshops for dissemination [ranging from 310k (£1,962) to 1.24 million Ksh (£7,848) per annum]; and finally, outlays for computer software packages to perform data analysis [308k Ksh (£1,949) per annum]. KMD costs amount to 24 million Ksh (£151,899) in year 1, and fall to approximately 6.2 million (£39,240) thereafter.

The county level advisory is not the work of the KMD decentralised provision alone, but the result of an inclusive discussion between key stakeholders. The study includes the cost of the PSP workshop/ CCOF – an event that produces the advisory, and totals 3.62 million Ksh (£22,911) per annum. In addition, ADS assist the CMO by sending information through an SMS network, via their extension team working to communicate forecasts and advisories, at 871k (£5,512) and 1.2 million Ksh (£7,594) per annum respectively. Finally, the Ministry of Agriculture has a large extension team who communicate the advisory as part of their range of farm-based support services at 2.25 million Ksh (£14,240) per annum. All together the development, printing, dissemination and communication of the advisory costs 7.94 million Ksh (£50,253) per annum.

Table 9 provides an overview of all establishment and maintenance costs associated with the development, construction, dissemination and communication of the KMD decentralised provision – 28m Ksh (£181,709) in the year 1, and 14m Ksh (£89,494) thereafter. Establishment costs are higher than maintenance costs due to the construction of a new premises and purchase of vehicle. What remains are the core personnel, data collection, capacity building, coordination, dissemination and communication costs.

Table 9: Costs of KMD Decentralised Provision including Dissemination/Communication Assistance

Type	Details	Total (Ksh)
Year 1 Establishment Costs		
KMD County Building	New Building	12.19m
KMD County Staff	Director, 3 x Technicians, Communication Officer	4.18m
KMD Transport	Vehicle, Maintenance, Fuel	2.69m
KMD Equipment, Data Collection, Dissemination	Rain Gauge Inspection/Maintenance, Internet, Training/Review Workshops	1.51m
PSP Workshop	Meeting, Printing Advisory, and Distribution	3.62m
ADS Communication & Extension Services	SMS Communication, Daily Rates for Extension Staff, Printing Costs	2.07m
Min. of Agriculture Extension	Daily Rates and Transport	2.25m
		28.71m
Annual Maintenance Costs		
KMD County Staff	Director, 3 x Technicians, Communication Officer	4.18m
KMD Transport	Vehicle Maintenance and Fuel	192k
KMD Equipment, Data Collection, Dissemination	Rain Gauge Inspection/Maintenance, Internet, Training/Review Workshops	1.82m
PSP Workshop	Meeting, Printing Advisory, and Distribution	3.62m
ADS Communication & Extension Services	SMS Communication, Daily Rates for Extension Staff, Printing Costs	2.07m
Min. of Agriculture Extension	Daily Rates and Transport	2.25m
		14.14m

7. Costs and Benefits of the KMD Decentralised Provision

The following section compares the inflation adjusted and discounted[2] costs and benefits of establishing and maintaining the KMD decentralised provision: subsection 7.1 explores the impact of uncertainty on NPVs by analyzing different uptake scenarios for the local level seasonal forecast and advisory; sub-section 7.2 uses figures of cost and benefits to develop a break-even analysis showing when investors see returns.

7.1 NPV and BCR

The analysis assumes a 10-year project lifecycle for the KMD decentralised provision. As Section 5.1 states, coverage possibly lessens in more remote areas, and to account for this outcome the analysis develops 3 coverage scenarios of 100%, 85% and 70% – the latter two scenarios simulate smaller proportions availing of local seasonal forecasts and advisories. Further, documenting scenarios within the analysis provides a basic sensitivity test to account for uncertainties associated with the practical implementation of initiatives.

Table 10: Net Present Values and Benefit-Cost Ratios (Ksh)

Costs	Scen. 70%	Scen. 85%	Scen. 100%	NPV	BCR
96.2m	107.6m			11.4m	1.11
96.2m		130.7m		34.5m	1.35
96.2m			154.3m	58.1m	1.60

Table 10 reduces the inflation adjusted and discounted costs and benefits in a single NPV showing the magnitude of returns. The decision rule suggests investments are economically/socially viable if net benefits are positive. The analysis shows positive returns [between 11.4m million Ksh *(£72,152)* and 58.1 million Ksh (£367,723) in all scenarios, and rise considerably when fully accounting for the proportion of recipients availing of the KMD decentralised provision with the sample.

Alternatively, the BCR demonstrates the returns of investing in the KMD decentralised provision in value for money terms, and an economically viability BCR needs is greater than 1. For every Kenya Shilling invested in the local seasonal forecast and advisory, investors receive between 1.11 (70% Scenario) and 1.60 (100% Scenario) Kenya Shillings. This findings indicates that even the most cautious scenario provides an annual return of just over 1% over 10 years, whilst full benefits are associated with a 6% annual return [see section 8 for efficiency aspects of value for money (Watkiss et al, 2014)].

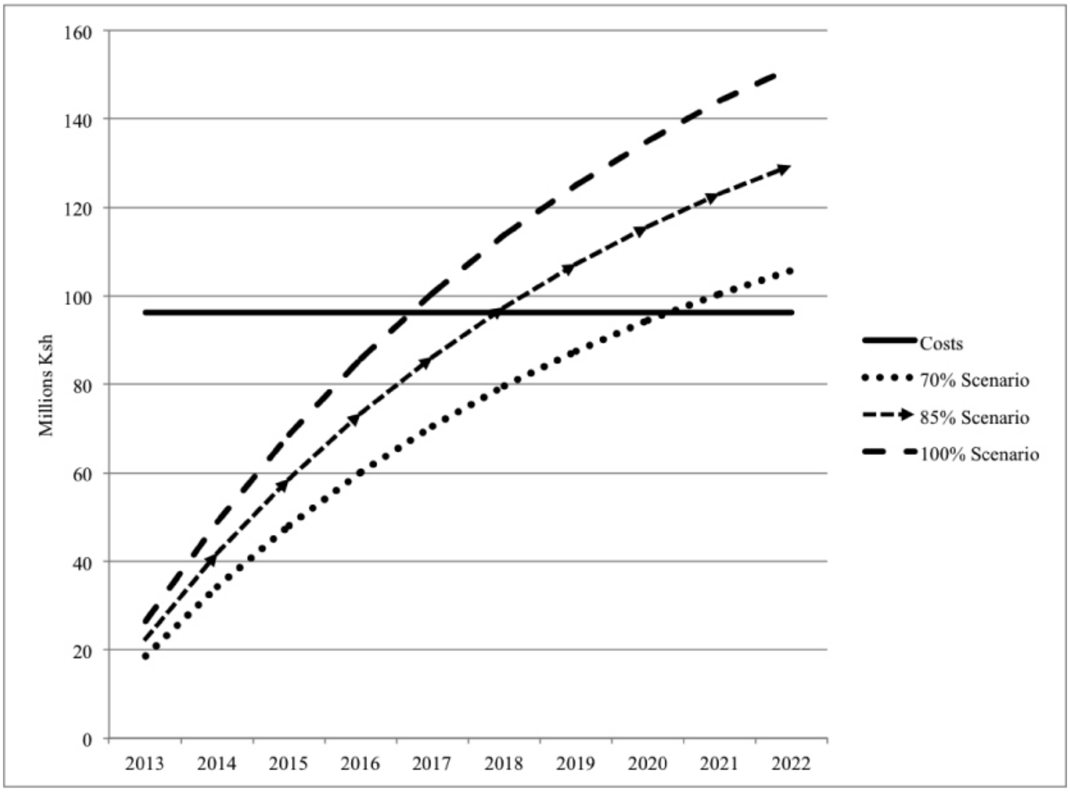
It is worth considering the above figures are generated using a complete account of all possible assistance given to the CMO in generating, disseminating, and especially in the communication of local weather and climate information, not just the seasonal forecast which is considered here. Excluding the costs of the PSP, and assistance given by ADS and Ministry of Agriculture's extension team, would ensure far greater economic returns, but would be a partial account of the practicalities of implementation.

2 Inflation rate is 5.7% (2014); Discount rate is estimated as the annual return on low risk corporate bonds (8.23%), as the optimal indicator of time preference.

7.2 Break-Even Analysis

A further consideration is if/when the KMD decentralized provision will generate a return on investment. The break-even point is the intersection where total accumulative fixed and variable costs are the same value as benefits. At this point, investors cover outlays for the KMD decentralised provision and begin to receive returns.

Figure 3: Break Even Analysis of the KMD Decentralised Provision



Weather and climate information products require time before benefits begin to accumulate. However, as the focus here is primarily the local advisory, learning to adapt and use the information in livelihood planning and decision-making is far less of a challenge, as instructions accompany the local forecast, and communication assisted by support services. As a consequence, benefits are assumed to accrue from the outset. The 100% and 85% scenarios create positive returns between 3–5 years, and the 70% scenario requires 8 years before recovering the initial investment.

8. Discussion

The households in Kitui County are using KMD decentralised weather and climate information to refine existing livelihoods, and are likely switching to less climate sensitive productive activity when the indications suggest below normal rainfall. In particular, local advisories enable smallholders to reduce losses from inappropriate crop selection and management, increase yields from climate resilient farming and livestock, and take-up, and benefit from, alternative livelihoods. Crucially, these informed actions provided households with benefits that were higher than the costs of delivering information. Yet it is important to consider this finding was taken from a timeframe (Sept. 2014 – Sept. 2015) when accurate below-normal forecasts were given, and the magnitude of these benefits may vary when rains are normal or above normal, or when forecast inaccuracies occur.

The study emphasizes the importance of recognizing smallholder adaptations are not limited to agricultural practices, but also include transfers of labour and capital to other sectors. International funders' are increasingly interested in the capacity of smallholder farmers to intensify existing livelihoods ('stepping-up') and adopt perhaps less climate sensitive off-farm job opportunities ('stepping-out') (DfID, 2015; Dorward et al, 2009). Clearly, there is a role in this process for locally contextualised and communicated weather and climate information services. Therefore, an important accompaniment to this study would be a follow-up investigation into the specific pathways and informed decisions through which households successfully intensify existing livelihoods, or adopt alternatives with positive impacts on income.

In terms of other studies in Kenya, KMD (2014) focus on an implemented seasonal forecast initiative with BCRs between 1.64–2.38, which are higher than KMD decentralised provision with 1.11–1.60. However, the latter accounts for alternative explanations in the outcome, while the former study omits such considerations in research design. Simulation-based studies in Kenya [e.g. Hansen (2009) and WMO (2015)] use marginal yield improvements as the overall metric, which means cross-study comparability is problematic. Assumptions-based studies combine the benefits of weather and climate information over different contexts, and suggest increases in Kenya's Gross Domestic Product. Therefore, at this time, comparing efficiency aspects of value for money within Kenya is only possible with the KMD (2014) study.

Using broader comparisons of weather and climate information, White and Rorick (2010) focus on disaster risk reduction in Nepal, using early warning systems, and find a comparable return on investment – BCR 1.55–2.79 – from assumed capital saved. Naturally, investment yields are far higher for industrialised countries, especially when assuming benefits for systemic improvements in meteorological infrastructure. Leviäkangas et al (2007) documents a BCR 1:3 for meteorological services in Croatia for each year. Frei et al (2009) find yields of BCR 1:4–1:6 for several national meteorological systems. A similar study conducted in Africa by the World Bank Group (2015) uses assumptions to record much higher benefits – 1:30, 1:50 and 1:100 – for the establishment of meteorological infrastructure.

Finally, reaching outside the economic valuation literature for perspective on the returns from the KMD decentralised service, Piketty's (2013) seminal work finds capital returns over time and space approximate 5%. This suggests allowing for the full coverage scenario, the returns from investing in the KMD decentralised provision (6%) are above the long-term average of all investment types.

9. Conclusion

Findings show that access to the KMD decentralized provision in Kitui County is related to higher household income, whilst controlling for alternative explanations. Using climate and weather information to adjust household strategies – e.g. crop and livestock management, and redirecting assets and investments – has a positive effect on income and wealth. Appreciations in income are higher than the costs of providing such services, representing a solid return on investment, and indicate the economic viability of the KMD decentralised provision within Kitui.

As far as the authors are aware, this economic valuation of the KMD decentralised provision is the first analysis of an implemented weather and climate information initiative in Sub-Saharan Africa to account for alternative explanations in the outcome. Further, the investigation attempts to move the methodological debate on from ex-ante simulations of the 'potential' value of information exclusively for agricultural practice under varying assumptions. Instead the research applies statistical techniques to income variation in order to model the impact of information products and services – accounting for the complexities and challenges of implementation – whilst taking a broader perspective about how information influences decision-making for farm/non-farm livelihood strategies.

To be clear about limitations, the study only considers the impact of information on household income over a 12-month period. Many other means to measure impact – e.g. strategic planning within the County Government – and timescales are available to investigate the value of the KMD decentralised provision. A further constraint is the use of the third year of the KMD decentralised provision in Kitui to develop findings across a 10-year period. There remains room to improve the robustness of figures with further data collection and investigation.

The recommendation of this study is to continue to up-scale analysis, dissemination and communication of the KMD decentralized provision. Highly contextualized weather and climate information and advisories informed by it, provided to end-users by experts situated within the county administration can have positive effects on the livelihoods of households in this study. When considering the design of such approaches, the study also shows the importance of local advisories (as well as the local climate information needed to develop them) and of ensuring wide coverage in their dissemination as a basis for improving the BCR of the investments.

Yet, there is also a wider need to invest further resources to analyse implemented weather and climate information initiatives, so as to improve the evidence base in Sub-Saharan Africa. Investments are increasing across the continent, but little is known about actual returns and value for money. The benefits of directing capital towards the KMD decentralised provision are evident and comparable across time and space. The literature on the economic valuation of weather and climate information would benefit from a change in emphasis, from assumption and simulation-based approaches that do not account for the challenges and complexities of implementation, towards more empirical analysis of actual farmers, pastoralists and those engaging in alternative livelihoods as they information for planning and decision-making.

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Appendix A: Income Framework

Farming Crops: the monetary value of farm crops sold or exchanged outside of markets – as this is a measure of income from farming, the value needs to account for investment levels in farming by subtracting expenditures on farm inputs (e.g. seed, tools, hiring plough, fertilizer) from total revenue.

Livestock Meat and Produce: the monetary value of livestock meat and produce sold or exchanged outside of markets – as this is a measure of income from livestock, the value needs to account for investment levels in livestock by subtracting expenditures on livestock inputs (e.g. non-farm fodder, inoculations, transportation) from total revenue.

Non-Farm Labour: the monetary value of all labour conducted by all members of the household – this may include working on other farms and herds, employment in manufacturing, retail or other services, and public works programs.

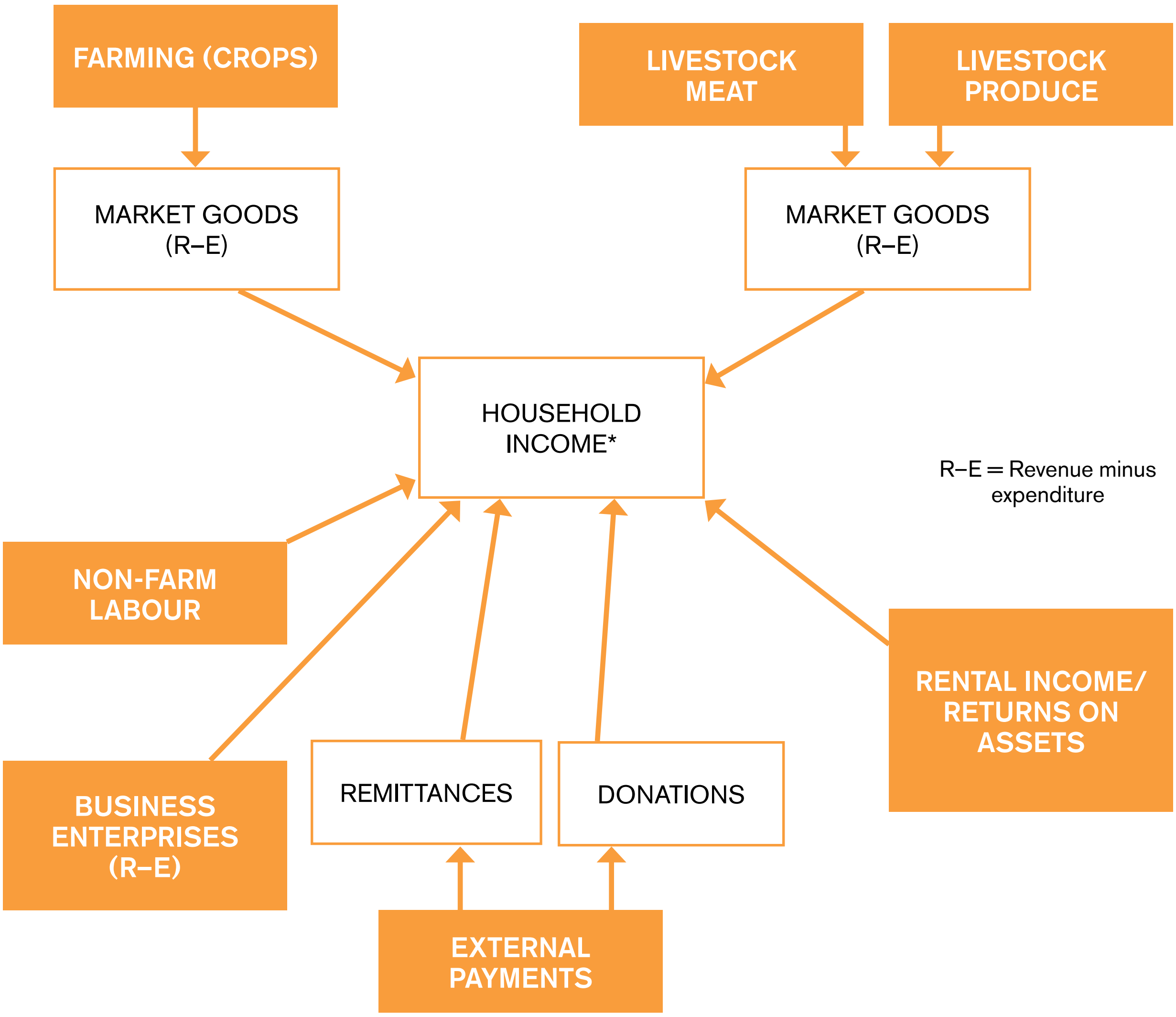
Business Enterprises: the monetary value of income generated from business activity by all members of the household – e.g. income from the sale of charcoal, sand, small-scale quarrying, general brokerage, transportation using own vehicle, retail.

External Payments: the monetary value of any payments made to any member of the household – this includes remittances of any kind, donations/payments made by church groups, non-government organizations, or other non-profit institutions. In addition, this can include payments from the National Social Security Fund (NSSF) and National Hospital Insurance Fund (NHIF) or other insurance/pension payments. Others include child support, alimony, or those relating to the lottery or prize bonds.

Rental Income/Returns on Assets: the monetary value of income from the rental of assets – this includes income from residential, commercial, land, subsoil assets or other property such as farm equipment, livestock. In addition, this may include a return for investing in business ventures.

This approach to income accounting **excludes the money received from the sale of assets aside from livestock within the reference period**, and thus lessens the possibility of anomalies arising from such decisions, and complications associated with valuing income and assets over the reference period. In addition, the approach **does not account for the consumption by household members of farm or livestock produce**.

R-E: It is difficult to collect information on family labour inputs, so we do not collect such information. Thus, we are unable to subtract the imputed family labour costs from the value of production, although we subtract the **Expenditures** or paid-out costs from **Revenues** when inputs are a necessary component of the income generating activity (this is also explained above). Accordingly, the crop, livestock, and nonfarm incomes should be considered as the sum of the returns on land, family labour and assets.


FARMING (CROPS)
LIVESTOCK MEAT
LIVESTOCK PRODUCE
MARKET GOODS (R–E)
MARKET GOODS (R–E)
HOUSEHOLD INCOME*
R–E = Revenue minus expenditure
NON-FARM LABOUR
RENTAL INCOME/ RETURNS ON ASSETS
BUSINESS ENTERPRISES (R–E)
REMITTANCES
DONATIONS
EXTERNAL PAYMENTS