Perception of Environmental Spillovers across Scale in Climate Change Adaptation Planning: The Case of Small-Scale Farmers' Irrigation Strategies, Kenya

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ABSTRACT

The failure to acknowledge and account for environmental externalities or spillovers in climate change adaptation policy, advocacy and programming spaces exercabates the risk of ecological degradation, more so, degradation of land. In particular use of unsuitable water sources for irrigation may increase salinisation risks. However, little if any policy assessments and research effort has been directed at investigating how farmer perceptions mediate spillovers from the ubiquitous irrigation adaptation strategy. In this study cognitive failure and/or bias construct is examined and proposed as an analytical lens in research, policy and learning and the convergence of disaster risk reduction and climate change adaptation discourses. The findings from small-scale farmers, Machakos and Kakamega counties, Kenya, suggest multifaceted biases and failures about the existence and importance of externalities in adaptation planning discourses. Among other dimensions, cognitive failure which encompasses fragmented approaches among institutions for use and management of resources, inadequate policy and information support, as well as, poor integration of actors in adaptation planning accounts for adaptation failure. The failures in such Human-Environment system interactions have the potential to exercabate existing vulnerability of farmer production systems in the long run. The findings further suggest that in absence of risk message information dissemination, education level, farming experience and information accumulation, as integral elements to human capital, do not seem to have significant effect on behaviour about mitigation of environmental spillovers. Implicitly, reversing the inherent adaptation failures calls for system approaches that enhance coordinated adaptation planning, prioritises proactive mitigation of slow onset disaster risks and broadens decision support systems, such as, risk information dissemination integration into the existing adaptation policy discourses and practice.

Key words : Adaptation failure, Adaptation planning, Economic interests, Climate Change, Ecosystem spillovers, Policy, Risk perception, Transformation

Introduction

Though climate change is used as justification for environmental and livelihood interventions [1], there is risk of adaptation failure or inability of adaptation action meeting set objectives and/or generating hybrid risks, such as, environmental degradation [2,3]. Accordingly, disaster risk drivers, such as, poor land management, unsustainable use of natural resources and declining ecosystems, have emerged as focal points in climate change action and pursuit of Sustainable Development Goals[4,5]. The growing evidence of links between climate change adaptation (CCA) and disaster risks has also seen concomitant efforts at integrating Disaster Risk Reduction (DRR) and CCA[6], with a focus on the dialectical and /or trialectic tension between resilience, adaptation and risk management within the broader social ecological system approach, particularly the human-environment nexus [3,7]. Analytical lenses that link climate change adaptation to other drivers of change has thus emerged as essential for effective adjustment to changing climate stimuli [8].

Comprehensive adaptation planning frameworks addresses policy and implementation processes interlinkages or scales at local and national levels[3,9, 10]. Implicitly it encompasses the integration of sustainable development and disaster risk management lenses [11,12,13], policy engagement or framing [2,3,9,14], as well as, changes in policies and institutional arrangements that mediate successful scaling up of CCA [1]. Risk management and robust decision making are core features that address underlying risks[15], moreso responses to adaptation needs that span long time horizon[16].

Innovative lenses on deliberations about risk appraisal [17], the role of values, interests and institutions that constrain societal response to change and unpacking of underlying causes are some of the factors of interest in the emerging approaches to climate risk management[11,14]. However, inspite of the recognition of the need to integrate DRR, climate change and sustainable development and their successes at conceptual level, insufficient interrogation of the underlying risks tend to bias disparate adaptation planning discourses towards Business as Usual (BAU) implementation trajectories that undermine effectiveness of adaptation action [18,19]. Most importantly, BAU or routine adjustment to adverse impacts from climate change tend to ignore social costs which is at cross purpose with some of tenets of sustainable development. There is urgent need therefore to reorient adaptation planning frameworks so as to minimise the risk of adaptation failure.

Social structures mediate exchange of knowledge and behaviour, such as the development and diffusion of adaptation technology to climate change [19]. In essence cognition or knowledge about risks and shared understanding could build coherence and vision into integrative frameworks, such as those that concurrently address sustainability and disaster risk reduction [11,20]. Accordingly values, beliefs, interests, knowledge and expectations are considered integral to holistic approaches and effective adaptation [3]. However, many of the existing integrative models are constrained as they fail to recognise the centrality of individuals [11]**.** Additionally, current integrative models pay low attention to time related concerns that may amplify the risk of slow onset disasters [21]**.**

The individual agency and wider pathways of change which portend challenges in adaptation discourses [22], are related to the complex social networks and relations in which people are embedded, commitments and understanding of social and ecological risks [7,14]. Accordingly, complementary efforts that address questions of scale, fit and interplay in policy and governance could partly resolve such dilemmas[23,24]. In this article, we explore how multifaceted biases and failures about the existence and importance of negative externalities constrain system integration in adaptation planning discourses.

Though integration of CCA and mitigation of associated disaster risks or ecosystem spillovers, such as salinisation risks, can be advanced through theoretical and/or conceptual multiplicity [25] convergence of CCA and DRR is constrained in agricultural production systems [7]. The constraints are related to difficulties in the integration of learning, reflectivity and change management, as well as, lack of institutionalization of CCA-DRR into the planning process [11,14]. More specifically, there is paucity of knowledge in diagnostic procedures and empirical evidence that illustrate conceptual and theoretical convergence, as well as, urgency for action [2]. In particular, there are gaps in adaptation policy framing especially on potential mechanisms for integration of CCA- DRR models [6]. We posit that environmental externalities, as an analytical lens, has great potential to facilitate holistic vision on the convergence and operationalisation of the often disparate CCA-DRR approaches.

Though system integration at local and global scales has emerged as critical in sustainability discourses [7], there has been low attention on environmental spillover effects [26,27]. The low attention to environmental spillover effects is more widespread in climate change action. In risk analysis, fast and frugal heuristics is adopted if ignoring some information does not compromise accuracy of the findings [28]. We adopt the logic and concur with Reed, Fraser, & Dougill, [29] , and Reid & Coleen, [30], that thresholds and sustainability indicators on a limited number of parameters, such as soil health (including qualitative aspects, such as salinity levels), can be used as empirical indicators to assess the effectiveness and/ or failure of adaptation strategies, such as, irrigation. In particular, we adapt [31], to the view that temporal variation in soil salinity, is an appropriate indicator in the monitoring of degradation risks and proxy for sustainability trends.

To illustrate our proposition, we assess various dimensions of cognitive failures and/ or biases in autonomous adaptation pathways among small-scale farmers and how this constrain transformative adaptation discourses. Building upon the above assumptions, we employ survey study and assessment of salinity dynamics to unpack the interplay between cognitive failure, environmental externalities and adaptation failure. The quantified changes and significance whose interpretation is based on FAO[32], classification of salinity risks from irrigation water, and metacoupling and/or telecoupling) principle [33,34], is assumed to provide time scale scenario of salinity and/or sodium hazard risks.

By unpacking the poorly understood environmental spillover effects, we provide insights that complement and enhances the utility of existing transformative adaptation planning frameworks. The nested adaptation assessment model provides holistic lenses that addresses multifaceted biases at policy, research and implementation levels, with potential to address complex interplay between the climate system, the human system, as well as, sustainability concerns, related policy analyses and ultimately system integration in adaptation planning. In so doing, the study contributes to the development of a robust and innovative diagnostic approach that integrates empirical data, cognitive and scale dynamics (such as, institutional polices , farmer management practices) in projecting adaptation failure.

The article is organised into several sections. Section 2.1 contextualises the limitations of policy and decision pathways in adaptation planning discourses across scale; section 2.2 discusses the environmental externalities/and or social costs and possible reasons for cognitive failure across scale. Section 2.3 attempts at extending the concept of transformative adaptation in the context of underlying risks while section 2.4 discuses salinity footprints as one of the slow onset disaster and an environmental externality that is given low attention in adaptation planning while section 2.5 gives an overview of climate change adaptation policy in Kenya. Section 3 discusses the methodology including the instruments used, data collection and analysis. Section 4 presents results and discussion while section 5 gives the conclusion and recommendations.

2.0 The multifaceted dimensions to cognitive construct in adaptation policy

The following section discusses the multifaceted dimensions to cognitive failure and/or bias construct in adaptation planning discourses. Section 2.1 to 2.4 thus explores how provides the construct mediates transformative intent. Perception and quantification of salinisation risks, as an example of less acknowledged environmental externalities among small-scale farmers practicing irrigation, an adaptation technology, is presented.

2.1 The policy- practice divide as cognitive failure

The development paths and the choices that define adaptation choices have greater bearing on the severity of future climate impacts [35], local-scale Disaster Risk Reduction (DRR) and resource management, as well as, broader social dimensions, such as risk perception [36]. Though planned adaptation presents new opportunities in the mitigation of climate change related risks [37], reactive or autonomous adjustments to adverse climate stimuli and the associated investments may increase the risk of maladaptation, hence an increased exposure of ecosystems, sectors or social groups to hybrid or secondary risk [19,38,39]. For example, adoption of technologies in water management, such as in flood control, has potential for new downstream hazards, in itself an example of negative interactive impacts between adaptation, governance failures and disasters [40]. The environmental damage and lack of fit for purpose associated with such interactions has been termed as adaptation failure [2, 3,9].

Optimising the benefits and concomitant minimisation of maladaptation risks through robust adaptation-mitigation-sustainability frameworks has emerged and suggested as a triple win strategy in adaptation policy framing [3,9,41,42]. Accordingly, effective formulation of adaptation strategies, as well as, the success of CCA policy and programming in climate risk management, to a large extent, is predicated on local knowledge of adaptation [43], local context of adaptation strategies [44,45], as well as, agent perception [9,46,47]. In addition, effective adaptation depends on policy support that facilitates environmental sustainability, as well as, enhance financial returns, knowledge stocks as some of the livelihood capitals [44]. Identification of causes, agents and flows behind the externalities or spillovers is thus critical to the understanding mitigation of externalities [7, 23].

Decision making is unpacked through adaptation activity and solution spaces that include the individual, technology, livelihoods, behaviour, the environment, institutions, as well as, popular and policy discourses [1]. Enhancing better understanding and managing effects across multiple systems and scales is thus critical in sustainability policy and management. In particular, the use of human perception lenses has immense potential in promoting system resilience [7, 48]. However, individual adaptation hinges on whether an impact, anticipated or experienced, is perceived as a risk and whether it should and/or is acted upon through adaptation policies, or is constrained by inertia and cultures of risk denial [20]. This necessitates the use of holistic approaches that consider feedback loops to shape outcomes from the complex interplay between the climate system, the human system and ecosystems, as well as, assessment of sustainability[2,9,7, 49].

The multiple interactions between governance and resource users' systems are consequential on provision of ecosystem goods and services, as well as, externalities [23]. Accordingly, under the sustainable development paradigm, ecological considerations are prioritised over short-term economic pay-offs [50]. In situations of inadequate information, and where alternatives and consequences are not well understood, the polluter pay and the precautionary principle [51], are widely accepted to compliment legislative and enforcement mechanisms in the mitigation of negative spillovers or externalities [51, 52]. However, for most developing nations, the precautionary and polluter pay principle, have been adjudged to be ineffective in the mitigation of environmental externalities [2, 53]. Pursuit of sustainability has thus been re-oriented to encompass coordination mechanisms and integrative use of social ecological lenses that unpack the complex interplays between agent cognition, governance, social and policy discourses with regard to outcomes, such as, environmental externalities[7,23]. Accordingly, synergies and trade-offs between broader development goals and climate-risk management have are the focus in adaptation planning [2,54]. However, environmental spillovers or downstream costs, such as, salinisation have received low attention in such discourses.

Though agent behaviour across scale, the processes in behaviour development, as well as, behaviour patterns can be exploited in scenario building of likely spillover impacts [55], lack of understanding and concern for important linkages between natural resource management, development, DRR, and climate change mitigation and adaptation constrain systemised planning [19,56]. For instance, policy makers, depending upon their institutional biases, may view a single hazard, such as, waterborne diseases and flooding separately, instead of multiple, interrelated hazards at a time[9,40], focus on immediate adaptation needs during policy framing and decision making [14].

Reducing the risk of adaptation failure depends on the extent to which multiple actors across scale and the broader social contexts are integrated into decision making [2,14, 19, 57, 58], as well as responsive legislative frameworks[57]. Information and policy coherence [9], coordinated framing of the problem among actors with influence on adaptation planning and policy tend to substantially reduce such risks [19,58]. Policy and information support frameworks have great potential to guide informed decision making and a paradigm shift towards effective adaptation action in general, and learning and mitigation of negative social and environmental externalities in particular [9].

Inspite of adaptation-mitigation-sustainability frameworks, accounting for environmental spillovers in planning processes remains as a challenge [7]. Such a challenge is routinely encountered in search of solutions to environmental change problems with intractable feedback loops [59]. Furthermore, the preferred biased end state solutions and technology approaches in routine adaptation discourses by default fail to acknowledge and account for environmental footprints [60, 61]. Such challenges may require use of metacoupling and/or telecoupling (which we consider as a subset of Metacoupling) approaches and their adaptation to local scale [7, 33,34]. This is in addition to use of innovative social and technical lenses (2,15,54,62], more so at individual level, where autonomous adaptation, local knowledge and perception of climate change tend to dominate over planned adaptation [63,45].

Telecoupling frameworks links actors, causes, flows and effects between and within sending(source) and receiving(sink) systems i.e. the entire socioeconomic and environmental chain interactions across time space and organisational levels [7]. The metacoupling framework differentiates between human-nature interactions within a system (intra coupling),between distant systems (telecoupling), and between adjacent systems or pericoupling [34]. Implicitly, it connotes a focus on underlying risks and /or incentives that influence agent behaviour, as well as, frameworks that link the upstream decision making phase and concerns for downstream impacts across scales which is of practical, policy and research concern.

As adaptation and mitigation in agriculture are country and farmer specific and by farmer characteristics, such as, farm size and education level[64], risk reduction planning process involves a diverse solution space, such as, knowledge of situations (cognition), processes and systems [3,5,11,14]. The low institutional awareness and institutional coordination between agencies responsible for disaster management and climate change adaptation, as well as, overall development planning thus tend to entrench the reactive and/or fragmented adaptation solutions[6,12].The divergence is reflective of cultural cognitive institutions that affect system understanding, boundary setting and participatory search for solutions [2, 11]. This may result into biased planning frameworks and adaptation failure [40,65]. Implicitly holistic approaches that pay attention to feedback loops between the climate system and the human system are invaluable in adaptation planning [49]. In particular, multi-hazard and multisectoral frameworks that foster people centred, collaborative partnerships, mechanisms and institutions for implementation of instruments relevant to building resilient socio-ecological systems are critical.

2.2 Cognitive failure and mitigation of Ecosystem risks

Though the three domains of adaptation, mitigation and productivity are dialectically related to the other two and thus intricately intertwined [66], operationalising system convergence is undermined by absence of over-arching national policies that integrate CCA and DRR into various aspects of land-use planning and typified by lack of capacity to assess, interpret and apply data on climate change risks and vulnerabilities, as well as, bottlenecks in the integration of plans among and within agencies [12]. The dissonance between individual values and formalised institutions and organisations as entry points for alternative adaptation pathways[22], and convergence between CCA and DRR is thus likely to demand substantial institutional changes [6].

Knowledge about consequences, their causes and implications play a role in peoples risk belief and mitigation actions [67]. Cognition or perception aid in mobilising peoples' commitment to action over environmental problems [68]. Perception of risk, habit, social status, and age as individual attributes are thus critical in collective action decision-making [20]. At community level analytical and conceptual lenses that unbundle cognitive biases and failures, as well as, integrate and transform individual and collective agency are critical in risk reduction and resilience building[69]. Theoretical and empirical multiplicity lenses improve analytical rigour, address conceptual and knowledge gaps, as well as, solve complex problems and contextual dilemmas while encouraging synergies[25,59]. The utility of communication in CCA-DRR convergence discourses at different instutional scales[6,70], as well as, development and dissemination of adaptation technology options [71], is thus critical.

The increase in risk and vulnerability from climate extremes calls for increased attention to an array of underlying drivers and lenses, such as, ecosystem services, governance and information needs [23]. However the dilemma arises due to divergence in priorities at different times and scales hence the need for analytical and policy innovations that advance and/ or broker complementarity in CCA policy, advocacy and programming spaces [1,70]. However, the complex Human-Environment system feedbacks are potential dilemmas that may constrain planning. For example, though awareness plays acritical role in disaster mitigation [67], increased information may be ineffective as a tool for better decision making where profit motive (proxy for risk disposition) prevails [72]. Intuitively there is need for innovative lenses that resolve inherent value conflicts around immediate private gain and concern for long term social gains.

Though changes in external stimuli, such as, temperature and moisture are sources of risks that trigger development of robust adaptation strategies at micro i.e. individual farm level [73], the farmer as a primary actor in adaptation planning, is motivated by short-term reactive incremental adaptation that are biased towards immediate economic interests and/or survival objectives other than long-term sustainable risk reduction initiatives [9,47, 74]. Prioritisation of narrow economic interests and immediate payoffs as opposed to long term social good, discounts the importance of future risks and undermine sustainability of ecosystems [1, 75].

Though collective action and public support is a necessary condition for the effectiveness of mitigatory action (i.e. internalisation of environmental effects, such as, methane emissions and salinity spillovers), the accruing benefits from such action, are felt after long time lags and spread or diffused to the wider social system, qualifying them as public goods, hence of low worth to an individual actor[47,76]. This seems to explain the popularity of adaptation pathways whose benefits largely accrue to individuals, over those that address underlying risks such as the negative ecosystem externalities or spillovers. In essence, effective adaptation planning need to consider and integrate short term and long term social interests in the mitigation of slow onset disaster risks.

In climate change adaptation, sustainability is oftenly framed as one way driver of change in the system of interest with little attention to feedbacks between the system of interest and other systems [7, 19, 77,78] ,as well as, poor cognition of spillover systems [33]. The cognitive barriers are linked to poor quality and/ or lack of specific information, poor coordination across scale [9], fragmented understanding among the actors[2, 63], as well as, operational challenges among constrained agents [3]. Cognitive failure and/ barriers thus inhibit informed and sustained action [79]. The failure is exacerbated by ineffective implementation and/ or poor enforcement mechanisms (Pahl-wostl, 2009; Park et al., 2012), especially the mismatch between expert and lay perceptions of risk [80]. More importantly, most policy framings in CCA fail to consider externalities for various reasons, such as, political incentives that tend to favour short term policy support over long term system concerns[14, 40,81].

The bias towards immediate payoffs across scale increases the need for integration and use of perception at community level in the design, analysis and policy reframing on adaptation planning[1, 11,14]. Dissemination of information on such risks or risk communication, has been found to play a critical role in the abatement of externalities[82]. Framing of communication regarding mitigation of future risks is thus critical as it affects cognition and disaster risk reduction responses[68,83]. In particular, variation in perception is an important consideration because differences between lay and expert perceptions of risk impact the success of risk communication [80]. Investigating farmer perceptions could provide novel insights and advances in the concomitant integration of sustainability, disaster risk reduction, resilience building and development planning lenses into transformative adaptation discourses, as well as, identify governance gaps for the betterment of system integration frameworks.

2.3 Underlying risks and transformative adaptation

Several pathways such as transformation, vulnerability reduction, disaster prevention, preparedness, response and recovery and building resilience provide solution spaces for risk management and adaptation to extreme climate changes [84]. The extent to which underlying risks are addressed defines whether the adaptation pathway is transformative or incremental. While incremental adaptation relies on BAU trajectories, transformative adaptation considers alternative development priorities, preferences and pathways that address the social drivers and processes, as well as, incorporate early warning systems as disaster risk reduction tools and lens into planning processes[1,2,9,14]. Implicitly,transformative adaptation includes monitoring, evaluation and learning for improvement and policy support [9]. However, operationalising transformative adaptation has received less attention in practice[14,85].

Incremental adaptation discourses primarily focusses on technical approaches to improve predictive capabilities in adaptation planning cycle [2, 9,14]. Incremental adaptation frameworks are thus short of social lenses that can unpack underlying risks. In contrast, transformative adaptation frameworks address deep rooted causes of risk and vulnerability with the primary objective being to enhance co-benefits and minimise the risk of the adaptation deficit or failure [14,86]. Enabling drivers towards transformative discourses include the upstream dialogue and exploration of values and visions about future decision making processes [87]. Increased awareness on the less acknowledged salinisation risks could aid such forward looking planning.

Scaling up of adaptation could provide multiple co-benefits where public participation, awareness raising campaigns, law enforcement, as well as, strong political will exist [88]. Improved access to information about appropriate adaptation strategies appear to support adaptation processes and resilience building at local level [11,45], as well as, raise procedural questions for decision-makers [1], engagement with individuals might be a useful lens through which communities and practitioners are sensitised about risks with higher uncertainty that fall outside their more mandate, with a positive impact on the construction of a more dialectical approach to DRM/CCA and sustainable development in general [14]. We argue that transformation pathways should revolve around the multifaceted cognitive failure construct and environmental externalities.

Though media can be exploited to enhance the understanding of disasters, especially where, vicarious experience is concerned [89], some authors [e.g. 90], have found no relationship between exposure to sources of information or self-rated knowledge about climate change and support for climate change policy. Such dilemma could be resolved partly through participatory communication [91] and concomitant use of seamless support systems, such as, risk communication which have great potential to address cognitive biases and/ or failures [82]. In the next section, we examine salinisation, a slow onset disaster and demonstrate how environmental externalities could mediate adaptation failure.

2.4 Salinity footprints and adaptation failure

Water quality and its suitability for use in irrigation is judged on potential severity of problems that can be expected to develop during its long term use [32,92]. Total concentration of soluble salts (salinity hazard) in terms of electro-conductivity (EC); relative proportion of sodium to other principal cations (sodium hazard) expressed as sodium adsorption ratio (SAR); bicarbonate concentration relative to the concentration of calcium plus magnesium and boron hazards or concentration of boron or other toxic elements are the most important determinants of quality and suitability of water for irrigation [92].

Salinity is recognised as one of the greatest land degradation process and ultimate decline in soil productivity especially in arid and semi-arid regions[93, 94]. High levels of salts in water used for irrigation has been implicated to affect soil fertility and crop yield [95]. Salinity hazards or EC exceeding certain threshold levels reduce water availability in the root zone and cause 8- 86% drop in crop yields [32]. Such risks increase with use of ground water (.e.g. from boreholes) of high salt content for irrigation [96]. In particular, salinity negatively alters soil microbial and biochemical properties, metabolic efficiency and growth of soil microbes [97]. Though salinity in soils tend to significantly vary, it indirectly impact climate change through oxide (N_2O) emissions, hence an effect on global warming [98].

Though primary salinisation is associated with parent material mineralogy, secondary salinisation is dependent on agronomic practices, such as, fertilization, poor drainage and use of inappropriate water sources [31,99]. In a study of groundwater quality in the soutpansberg fractured aquifers, South Africa, agricultural activities produced localised impacts in terms of elevated concentrations of calcium, chloride, magnesium and nitrates in groundwater[100]. Where small scale production systems dominate, underestimation of cumulative impacts of the seemingly minor individual footprints may result to an ecological disaster in the long run.

Land degradation is one of the slow onset disasters with adverse social and ecological impacts [101]. For example, in India, one of the countries where land degradation is widespread, 6 Million hectares of the 147 million hectares of land classified as degraded, is attributed to salinisation [102]. Though slow-onset disasters, such as, land degradation generally do not result in sudden fatalities or casualties and acute property damage, they are more extensive in their impact and more destructive in the long term than rapid-onset disasters such as floods, hurricanes, and earthquakes[103]. Since individuals may not recognize land degradation as an underlying cause of vulnerability, awareness on such type of a disaster is critical [104]. Lack and /or poor knowledge of the consequences of the effect of such slow-onset disasters, such as those associated with spillovers from salinisation, fits the narrative of adaptation failure and demonstrates the intractable challenges between adaptation action and vulnerability to induced risks or spillover effects.

2.5 The Agricultural sector, climate change risk and adaptation policy context in Kenya

Kenya is predominantly an agrobased economy where small scale farmers dominate with about 75% of the populations' livelihoods directly linked to agriculture [105]. Agriculture is thus key to overall national development, equity objectives and sustainable growth. Intuitively, weather-related disasters, particularly droughts, present a major challenge to the predominant rainfed agricultural production system with profound adverse impact on the economy. The adverse effects negatively affect foreign exchange earnings, food security and nutrition, employment and rural livelihoods. Adaptation to extreme weather impacts is thus a priority under National Adaptation Policy Action plans (NAPAs). Among other objectives, NAPAs envisages improved crop productivity through irrigation [106].

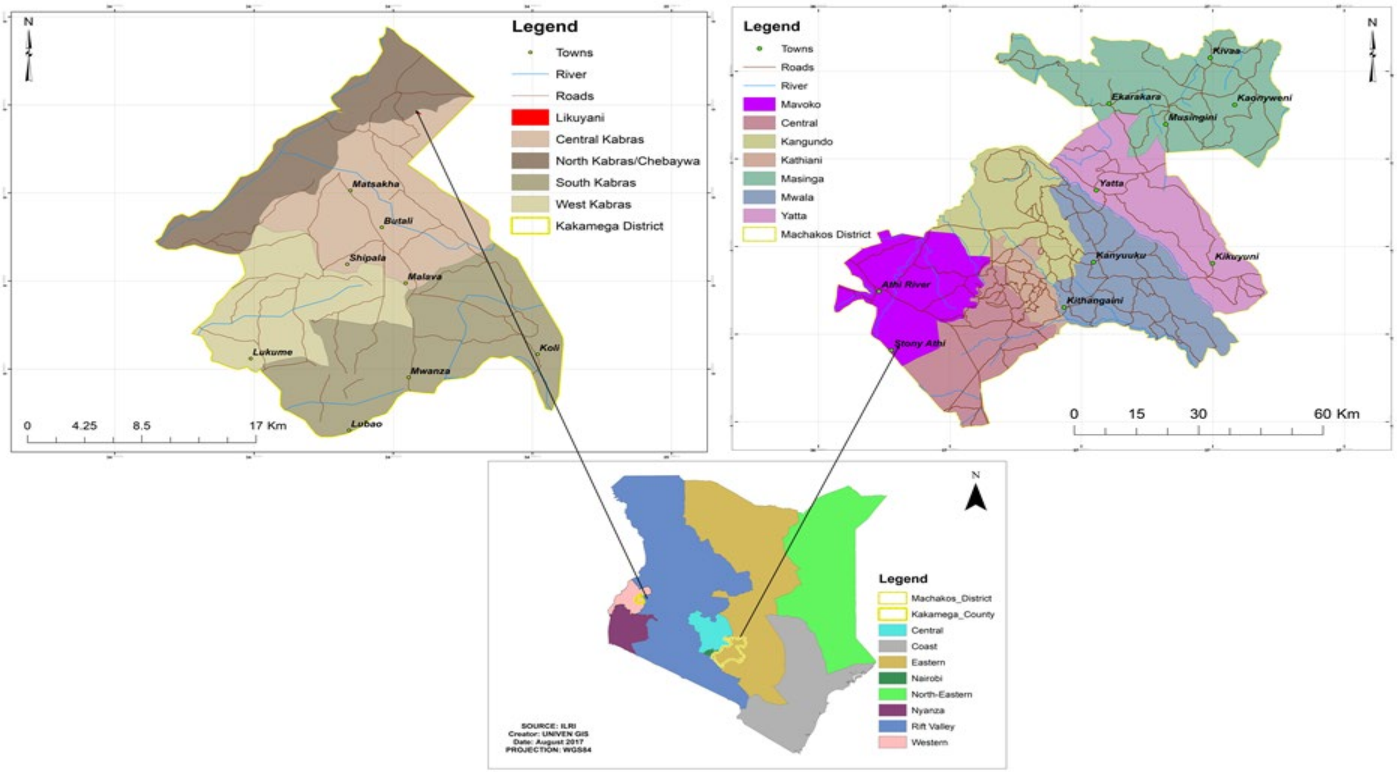
Adaptation to climate related risks is expected to be achieved within a number of institutional and governance frameworks, such as, the climate change Act and the Environmental Management Coordination Act (EMCA) which directly or indirectly impinge on agricultural sector planning. EMCA is a framework legislation under the stewardship of the National Environment Management Authority (NEMA), the government agency for coordination, enforcement and compliance on all matters on environment. As the principle instrument that establishes the legal and institutional framework for all matters that touches on environmental management in Kenya [107], EMCA adopts the "precautionary principle" as a sustainability safeguard in decision making. The 1st Schedule of the EMCA act, Part (vi) and (vii) provides for the process and projects that should undertake Environmental impact Assessments(EIA), Audit (EA) and monitoring respectively. Irrigation is among projects that should undertake EIA/EA. However, the Act only refers to effluents and not the processes nor the slow onset disaster risks, such as, salinisation.

Building farmer resilience to climate change risks is the main objective under the Agricultural Sector Transformation and Growth Strategy [105], which in agriculture operationalises the climate change Act. Though the Climate Change Act [108], broadly addresses mechanisms and measures towards low carbon climate development, it fails to address environmental externalities, such as, salinity footprints that are embedded irrigation, an ubiquitous adaptation pathway in the country. The Agricultural Sector Transformation and Growth Strategy envisages an increase in access to irrigation by small scale farmers from the current level of 5% to 11%.

3.0 Methodology

3.1 Study area

Fig (1) gives the map showing the location of Likuyani subcounty in Kakamega County and Mavoko subcounty in Machakos county respectively as the study sites. Though the study sites are located in contrasting ecological zones, they are highly populated and characterised by high poverty levels. High population and poverty levels are drivers of increased livelihood vulnerability to climate change related risks. Kakamega covers an area of 3,051 km² with a population of 1,660,651(approximated growth rate of 2%), that translates to population density of 544.3/Km². Machakos covers an area of 6,208 km² with a population of 1,098, 584 persons (projected growth rate approximated at 1%), and a density of 177.0/Km² [109].



SOURCE: ILRI
Creator: UNIVEN GIS
Date: August 2017
PROJECTION: WGS84

Fig 1: Gis Generated map of study sites in Kakamega and Machakos Counties, Kenya

Kakamega county is located in Western Kenya between longitude 34^0 35^1E and latitude 0^0 and 0^015^1 N [110]. The county is characterized by commercial sugarcane farming as well as maize production at subsistence and commercial level as major economic activities [109]. Agriculture employs 80% of the population and is critical to poverty (currently at about 50%) reduction in the county [111].The Agro ecological zones (AEZs) range from UM1 (upper middle-1) to LM-3 (Lower middle-3) hence variation in rainfall, agricultural potential and productivity in terms of livestock type, crop varieties and actual/potential yield levels [110]**.** Most of the soils in the county are thus heavily leached due to high rainfall and relay cropping.

The county receives 1200-2200 mm of rainfall per annum with the first rains of 500-1100 mm and second rains of 450-850 mm. However, farmers in the area, notably the northern part (the study site), is affected by extreme climate change extremes in form of droughts. The extreme weather episodes are exercabated by high evapo-transpiration that averages 1600 to 1800mm. Generally, the county has experienced warming trends, interannual variability in the amounts of rainfall as evidenced by increasing number of consecutive dry days, as well as, intense and downpours that occasion flooding [111].

Machakos county is located in Eastern Kenya, between latitudes 0°45´and 1°31´S and longitudes 36°45´ and 37°45´E and an altitude of 790 to 1594 M above sea level. The agriculture economy in the county contributes 70% of household income and is characterized by livestock farming, as well as, small-scale crop production at subsistence and commercial levels [109]. The AEZ range from LM2 (Lower middle-1) to LM-3 (Lower middle-3). The county is characterised by a semi-arid type of climate (except in highland areas) and cool to hot temperatures that averages 18˚C and 29˚C. It receives bimodal but unevenly distributed and unreliable rainfall that averages 500 mm to 1300 mm annually. The agricultural potential and productivity in terms of livestock type, crop varieties and actual/potential yield levels is thus highly limited by the low moisture potentials which increases vulnerability of farmers to production failures. The absolute poverty in the county averages about 61% [112].

3.2 Data collection

For this study, a cross sectional survey design was used at farm level to collect information from two contrasting agroecological zones through a multistage sampling technique. The agroecological zones in terms of counties and sub counties respectively, were selected on the basis of population pressure per square kilometre (High density- >600,400-599- Medium density and < 400 - Low density), rainfall amount and variability as factors that influence climate change and livelihood vulnerability severity impacts. The sampling frame consisted of a list of farmers from target villages provided by the department of agricultural extension in Likuyani and Mavoko sub counties of Kakamega and Machakos counties respectively. Proportionate stratified random sampling was employed with AEZ used as proxy for water availability, use strategies and salinisation risks in the first stage, hence Machakos and Kakamega counties. During the second stage, population density as proxy for land subdivision(land size) and therefore the extent of land resource marginalization was used to select villages where the questionnaires and soil sampling was to take place. The third and final stage employed irrigation typology and water source for irrigation. Households for the administration of the questionnaires were then picked through lottery system from a box of cards with numbers generated from a table of random numbers. The semi structured questionnaire were administered between December 2018 and February 2019. The information from household surveys were triangulated through Key informant interviews (KI) and Focus Group discussions (FDGs).

Desk reviews on climate change adaptation policies and environmental governance was also undertaken. Before data collection commenced, the survey questionnaire was tested among 10 respondents to ensure the adequacy of the information obtained and to avoid any ambiguity in the questions. The questionnaire sought information on farmer risk reduction measures concerning soil and water soil testing and associated factors around dissemination of information on salinisation risks (Appendix I). Systematic sampling was employed in the collection of soil and water samples (i.e. on basis of whether ground water (e.g. shallow well, borehole) or surface water(.e.g. rivers, roof harvesting) was the main source of irrigation water. Both top soil (0-20cm) and subsoils (20-40 cm) from irrigated and non-irrigated sections of farmers' fields were collect using a soil auger, packed and analysed using AAS (atomic absorption spectrophotometer) and flame photometer at the Kenya Agricultural and Livestock Research Institute KARLO, Kabete an ISO/IEC17025 accredited laboratory. This involved composite sampling where top and subsoil subsamples(four) from each farm(zigzag transect) were combined to make up a single composite sample. Composite sampling control for spatial and horizontal variations and improves the accuracy in estimation of population parameters thus reducing cost and analytical time [113]. It was assumed that each sample contributes equal amount to the composite and the interaction between the sample units would not significantly affect the eventual composite sample.

3.3 Data analysis

Statistical analysis was performed using generalised linear logistic Weight Estimation procedure in IBM^R SPSS^R statistics version 26.0 (SPSS Inc., Chicago, IL, USA). Weight Estimation procedure computes the coefficients of a linear regression model using weighted least squares (WLS), such that the more precise observations (that is, those with less variability) are given greater weight in determining the regression coefficients [114]. WLS thus tests a range of weight transformations and indicates which will give the best fit to the data i.e., the coefficients selected are those that make the observed results most likely. The weights can be interpreted as a change in the logarithm of the odds ratio E(β), associated with a one-unit change in any predictor. The odds equation [114] is given in equation (1). Negative E(β) suggest decreasing likelihood of falling into target group as you increase predictor variable while positive E(β) indicate increasing likelihood of falling into target group as you increase predictor variable.

$\Omega =$ ez/(1 + ez)……………………………..(1)
Ω is the probability of the event,
e is the base of the natural logarithms (about 2.718),
z is the linear combination and calculated as;
$z = a + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots + \beta_i x_i$
a is a constant (intercept)
βs are coefficients (the log odds) estimated from the data
x_i are the values of the predictors

The log of the odds ratio E(β) or logit expression is given as;
$z = \log(p/(1{-}p))$
Where P = Probability of falling into target group which is soil / water testing
1-p = lack of soil/ water testing

Heteroscedasticity which renders estimated ß's inefficient and thus invalid for use in making predictions about dependent variable was tested for through Pearson correlations(Fig.4). Though a hypothetical dimension of any social phenomenon can be investigated, the responses may be biased especially where farmers are not familiar with the variable being investigated [115]. Since occurrence of extreme weather and availability of communication media in extension is common in the two study sites, such biases were controlled for in the study. A hypothetical effect of risk dissemination was thus elicited to visualise if it could bias risk perception in terms of practices that impact salinisation risks. Soil (irrigation water) testing was assumed as the appropriate risk mitigation practice against salinisation. A paired t-test of significance was conducted to evaluate the difference in salinity risks associated with irrigation in the topsoil and subsoil (n = 19) for the two counties. The quantified changes and significance were assumed to provide time scale scenario of salinity and sodium hazard risks.

4.0 Results and discussion

The statistical analysis for changes in sodium in the top soil (ESP), an indicator of soil salinity hazards is given in Fig.2. There is significance difference in salinity hazards in the top soil with irrigation especially for soils in Kakamega county study site. The mean ESP in top and subsoil in Kakamega was 5.65± 3.73 and 5.91 ± 0.70 Me% respectively. The mean change in ESP was significant in both sites. The ESP for Kakamega changed by 0.66± 0.73 and -.08±0.40 Me% in top and subsoil respectively. The mean change in ESP for

Machakos study site was 0.033± 0.47and 2.22± 28.21 Me% in top and subsoil respectively. The overall change for the two sites with irrigation in the top soil and subsoil was 0.45±0.70and .69±9.8 Me respectively. The overall negative changes in ESP values for top soil imply displacement of calcium (ca^{++}), Potassium (k^{+}) and Magnesium (mg++), the bases that jointly determine cation exchange capacity (CEC) or indicator of fertility, as more of Na+ is being adsorbed on the soil surface. The increase in Na^{+} is indicative of soil degradation. The net negative change in top soil is indicative of soil degradation risks while the positive changes in subsoil soils is attributed to leaching of salts and potentially the degradation of underground water resources with time.

Fig 2. Paired Two Sample test for Means on ESP(Me%) and changes with irrigation(N=19)

		Treatment	Mean	Variance	T	Critical t-value	Significance
Kakamega(N=13)	Topsoil	Non irrigated	5.6	3.73	-7.57	1.8	**
		Change with Irrigation	0.66	0.73			**
	Subsoil	Non irrigated	5.91	0.70	-24.65	1.8	**
		Change with Irrigation	-0.08	0.40			
Machakos(N=6)	Topsoil	Non irrigated	1.4	0.428	-3.69	2.01	**
		Change with Irrigation	0.033	0.47			
	Subsoil	Non irrigated	1.85	0.84	0.201	2.01	**
		Change with Irrigation	2.22	28.21			
Overall(N=19)	Topsoil	Non Irrigated	4.2	6.69	-6.21	1.74	**
		Change with Irrigation	0.45	0.70			
	Subsoil	Non Irrigated	4.56	4.56	-4.12	1.74	**
		Change with Irrigation	0.69	9.8			

Source : Authors Statistical analysis of Soil samples, ** Significant at 0.05 and 0.001

The increase in subsoil Na^{+} levels for both sites could be attributed to leaching of salts under irrigation. The overall mean ESP for both sites was 4.2 with a change of 0.45 in top soil and 4.56 Me% in subsoil, a change of 0.69 me%. Overall, irrigation increased ESP in both sites , an indicator of soil degradation risks. The two sample F test for variance in Sodium concentration is negative, an indication of increased and high sodicity risks in Kakamega. Though primary salinisation effects were not determined, the increase in sodium concertation with irrigation is indicative of soil quality degradation risks in autonomous adaptation.

Fig 3: Two-Sample F-Test for Variance in top soil sodium concentration(SAR) with irrigation

	Kakamega	*Machakos*
Mean	-0.00769	0.133333
Variance	0.000769	0.062667
Observations	13	6
Df	12	5

F	0.012275
P(F<=f) one-tail	7.76E-09**
F Critical one-tail	0.32197

Source: Authors analysis of Soil and water laboratory statistical analysis, 2019; ** significant at .05%

Fig. 4 presents pearsons correlation on a number of factors influencing soil testing in the two study counties. There is positive correlation between education and income, awareness on risks on water ,as well as, the positive risk reduction inform of soil/ water testing. However age has a negative correlation. This is inspite the more aged believing that environmental risks can negatively impart them. Age is also negatively correlated to source of information. Possibly old farmers tend to rely more on informal sources of information such as their peers, other than the ubiquitous electronic and mass media sources. Age is also negatively correlated with income suggesting that it may constraint adoption of soil testing advisories.

Human capital theory [116], identifies innovative ability as closely related to education level, farming experience (proxy for age), and information accumulation. The positive effect observed for education on adoption of soil testing though not significant is consistent with human capital theory in Agriculture. However, the negative correlation between number of years in use of technology (an indirect proxy for age) and perception of harm from environmental risks is consistent with risk normalisation theory [89].The choice of channels of communication and their effectiveness is thus a critical policy consideration in transformative adaptation and sustainability discourses.

The communication perspective is critical in risk dissemination and sustainability discourses in climate change adaptation [117,118]. Information improves farmer's human capital, reduces risk and uncertainty in technology adoption process [119]. In this study, the negative correlation between information source and education in risk reduction behaviour is possibly related to biased access of information as the level of education increases. Further, the findings suggest a gap in the current research-extension linkages where access to information sources, such as, scientific journals that are more likely to disseminate information on environmental externalities as opposed to the conventional sources, such as, the radio are by default biased towards farmers with high levels of education. Since the effect of risk dissemination is negatively correlated with source of information, it suggest that the current source of information are ineffective/ and or do not disseminate information on the existing risks. Implicit in this is the need for transformative lenses in enhancing the role of media both electronic and print in risk information dissemination especially as relates to secondary risks in climate change adaptation.

Fig 4. Pearsons correlations on factors influencing soil testing in Kakamega and Machakos counties, Kenya

	(Intercept)	Age	NFIHH	FHH	EHH	AWR	*WS*	AHR	AER	SIH	BS	SIE)	L	SISST	IR
(Intercept)	1.000														
Age	-.416	1.000													
Non-farm income level Household Head(NFIHH)	-.320	-.264	1.000												
Farm income household head(FIHH)	-.536	.194	.377	1.000											
Highest education level - House head(EHH)	.131	.476	-.926	-.310	1.000										
Are you aware of any risks from water source (AWR)	.075	-.781	.393	-.195	-.566	1.000									
Source of water(WS)	-.568	.399	-.210	.221	.381	-.234	1.000								
aware of any health risks from water(AHR)	-.348	-.567	.537	.100	-.622	.611	-.141	1.000							
aware of any environmental risks(AER)	-.299	-.557	.065	.054	-.202	.640	.159	.632	1.000						
Source of information- Health	-.522	-.269	.667	.124	-.627	.521	.162	.686	.479	1.000					
believe environmental risk can impart negatively(BS)	-.048	-.064	-.213	-.219	.130	.164	.336	.044	.281	.076	1.000				
Source of information- Environmental(SIE)	-.473	-.027	.668	.445	-.647	.222	.013	.427	.153	.575	.302	1.000			
Whom did you get to learn about irrigation(L)	-.080	.399	-.469	.044	.534	-.379	.062	-.424	-.185	-.484	-.406	-.550	1.000		
specific messages on potential risks of different water sources on soil and their control (SISST)	-.004	.643	.095	.062	.127	-.587	.042	-.539	-.860	-.262	-.418	-.055	.244	1.000	
Types of irrigation(IR)	-.115	-.605	.057	-.089	-.242	.698	-.102	.542	.878	.343	.185	-.004	-.071	-.877	1.000

Source : Authors statistical analysis of field data, 2019

Fig 5 provides odds ratio E(β), generalised logistic parameter estimates on soil testing as a risk reduction measure and control of irrigation related risks, such as, salinity. Odds ratio less than one implies that the variable decreases the likelihood of adoption whereas odds ratio greater than 1 means that the variable increases the likelihood of adoption. The likelihood odds on age, farm income (farm and non-farm), number of years in use of technology, and source of information, education, awareness on health risks, type of irrigation though not statistically significant had negative odds. Without risk message dissemination, there is decreasing likelihood in soil testing with increase in value of the mentioned variables. From existing literature the negative sign of age is expected and could be linked to increase in risk aversion with age. However, education , income and experience tend to be positively correlated with adoption. The observation suggest that existing technology diffusion and adoption models and human capital theory in agriculture cannot be used effectively to address environmental externalities in adaptation planning.

Fig 5 : Generalised Linear logistic Parameter Estimates on soil testing without dissemination of risk messages

			Unstandardized 95% Wald Confidence interval					Standardized 95% Wald Confidence	
Parameter	β	Std. Error	Lower	Upper	Wald χ^2	Sig.	Exp(β)	Lower	Upper
(Intercept)	-22.572	1.6028	-25.714	-19.431	198.329	.000	1.574E-10	6.803E-12	3.642E-9
Age	-.052	.2414	-.525	.421	.046	.830	.950	.592	1.524
NFIHH	-.075	.2073	-.481	.332	.130	.719	.928	.618	1.393
FIHH	-.110	.1665	-.436	.217	.433	.510	.896	.647	1.242
EDHH	.186	.3147	-.431	.803	.350	.554	1.205	.650	2.232
AWR	.082	.8013	-1.488	1.653	.011	.918	1.086	.226	5.221
SW	4.855E-5	.0899	-.176	.176	.000	1.000	1.000	.838	1.193
AHR	-.224	1.0522	-2.286	1.838	.045	.832	.799	.102	6.287
AER	-.414	.7711	-1.926	1.097	.289	.591	.661	.146	2.996
SIH	-.033	.0847	-.199	.133	.154	.695	.967	.819	1.142
BS	-.089	.4321	-.936	.758	.042	.837	.915	.392	2.134
SIE	-.003	.0738	-.148	.141	.002	.966	.997	.863	1.152
L	-.027	.0715	-.167	.114	.138	.711	.974	.846	1.120
SSISST	.068	.7380	-1.379	1.514	.008	.927	1.070	.252	4.547
IR	.001	.1675	-.327	.329	.000	.995	1.001	.721	1.390
SI	.082	.2351	-.379	.543	.121	.727	1.085	.685	1.721
TT	.004	.0694	-.132	.140	.003	.957	1.004	.876	1.150

Source : Authors statistical analysis of field data, 2019. Likelihood Ratio Chi-Square (χ^2) = 10.858; p = 0 .286, df= 9

The positive effect of risk message dissemination on risk behaviour has been observed by several authors [e.g. 20,67,89]. Fig (6) provides Generalised Linear logistic Parameter Estimates on soil testing with dissemination of risk messages**.** In this study, dissemination of risk messages could have significant impact on likelihood of positive change on risk belief and mitigation action. This is consistent with some findings on rapid onset disasters such as earthquakes, where higher education levels, higher income and greater experience with previous emergencies has been shown to be significantly associated with higher preparedness [120]. Risk message dissemination has positive significant effect on farmers disposition about salinisation risks with majority of the farmers who would change their behaviour (adopt soil testing as a risk reduction measure) falling in the 30-49 years age category.

Fig. 6 : Proportion of Change in action for soil testing if risk message were disseminated

Age category	No	Yes	Total	% Change
20-29	5	2	7	3.13
30-49	15	18	33	28.13
50-59	8	6	14	9.38
60-69	3	6	9	9.38
70 and above	0	1	1	1.6
Total	31	33	65	51.62

Source: Authors analysis of field data

Likewise dissemination of risk message has significant positive impact on likelihood in change of choice of water sources (WS) for irrigation and type of irrigation (i.e. bucket, sprinkle, surface and drip), all which impact salinity hazards. Additionally risk message dissemination significantly increases the likelihood of soil testing for every additional level (higher level) of farmer education and the positively correlated non-farm income. However, dissemination of risk messages decreases the likelihood in soil testing when awareness on water and environmental risks are taken into account. This could be due to other factors, notably the extra costs incurred in soil testing, which is a source of risk with potential to decrease profit levels in the short term. The observation is consistent with [72], that gaps between information dissemination and level of implementation could be as a result of subjective limits or considerations for factors that impact profit and or/ cost in adoption of risk reduction behaviour. Factors that lower profits or increase expenses are sources of risk (.i.e. technical, price, legal, social and human), that adversely impact the economic performance hence farmers' decision making [121,122,123]. The finding underscores Howden et al. [124], and Koundouri et al. [119], observation that policy makers in adaptation planning need to pay attention to the role of risk attitude in technology adoption.

The significant decrease in likelihood of soil testing with risk message dissemination when the number of years the farmer has used a given irrigation technology is taken into account could be attributed to resource fixity in agricultural production (i.e. difficulty in changing irrigation infrastructure to alternative uses) and attendant risks and /or low risk belief about salinisation risks among farmers. The observation is also consistent with existing literature on determinants of cognitive bias, such as, personal experience, knowledge (level of education), extension education, which individually or severally impact cognitive ability and the accuracy of climate information processing [83]. The inherent social and environmental costs in maladaptive projects and their premature decommissioning at a future date may impose high opportunity costs to society at large when adaptation policy and practice ignores the integration of environmental spillover mitigation into planning. The observation highlights the need for system approach and innovative use of communication as a tool for proactive risk reduction and effective adaptation planning.

Fig.7 : Generalised Linear logistic Parameter Estimates on soil testing with dissemination of risk messages

			Unstandardized 95% Wald Confidence Interval				standardized 95% Wald Confidence interval		
Parameter	β	Std. Error	Lower	Upper	Wald χ2	Sig.	Exp(β)	Lower	Upper
Intercept	-84.523	4.1365	-92.631	-76.416	417.521	.000	1.959E-37	5.902E-41	6.502E-34
Age	2.782	1.0189	.785	4.779	7.454	.006	16.148	2.192	118.961
NFIHH	9.137	.7023	7.760	1.513	169.256	.000	9291.669	2345.799	36804.136
FIHH	-1.196	.3775	-1.936	-.457	10.045	.002	.302	.144	.633
EHH	.642	.9184	-1.158	2.442	.488	.485	1.899	.314	11.491
AWR	-9.560	2.4241	-14.311	-4.809	15.553	.000	7.052E-5	6.094E-7	.008
WS	.889	.1521	.591	1.187	34.195	.000	2.434	1.806	3.279
AHR	7.723	2.4725	2.877	12.569	9.755	.002	2258.738	17.752	287391.934
AER	-9.136	1.8365	-12.735	-5.537	24.748	.000	.000	2.945E-6	.004
SIH	.753	.2005	.360	1.146	14.085	.000	2.123	1.433	3.145
BS	7.058	.7838	5.522	8.594	81.096	.000	1162.039	250.086	5399.470
SIE	.228	.1929	-.150	.606	1.400	.237	1.256	.861	1.834
L	-.519	.1158	-.746	-.292	20.089	.000	.595	.474	.747
SISST	4.927	1.3643	2.253	7.601	13.040	.000	137.927	9.513	1999.787
IR	2.477	.4175	1.659	3.295	35.207	.000	11.908	5.254	26.990
SI	.353	.6015	-.825	1.532	.345	.557	1.424	.438	4.629
TT	-.618	.1765	-.964	-.272	12.251	.000	.539	.381	.762

Source : Authors statistical analysis of field data, 2019. Likelihood Ratio Chi-Square (χ^2)= 1.742E^{10}, Df= 7; P= .000*** ; Significant at .001%

Managing environmental risks in climate change action inadvertently touches on governance in terms of roles, availing of relevant information, policy and legislative frameworks, risk control guidelines, as well as, coordination mechanism that are responsive to the present and future needs of society [82]. The role of governance on soil testing as a risk management strategy was undertaken through KI, FGDs and desk reviews. The findings revealed key governance gaps, particularly fragmented approaches and coordination among government agencies, low awareness about salinisation risks among farmers and extension agencies, all of which constitute cognitive failure on environmental spillovers in climate change adaptation. Though the object of the Climate Action planning is to integrate climate risk and vulnerability assessment into all forms of assessment, and for that purpose liaise with relevant lead agencies for their technical advice, it tend to focuses only on methane emissions and fail to acknowledge the diverse array of environmental spillovers, such as the salinisation risks in irrigation.

In the study area, lack of coordinated approaches among various agencies was noted. Further, interviews with farmers and analysis of KI interviews revealed that neither the climate change Act nor EMCA identifies salinisation externalities. The cognitive failure was more apparent in extension agencies from both counties. According to KI interviews, the extension agents were more focussed on supply and demand needs with irrigation, a routine adjustment and solution to increasingly risky rain fed systems being recommended to the exclusion of underlying environmental concerns. This seems to be a popular discourse among policy makers, farmers and practionneers in the country.

> “Farmers who are able to afford the technologies, don’t consult on water and soil quality issues other than on aspects, such as, input sources and markets. Further some of the projects are funded by the central and county governments against tight timelines for example emergence drought recovery interventions which tend to be accorded high attention by the political class. We focus on technological dimensions, that is, the agronomic aspects, such as, fertilizer types, choice of variety and which are farmer felt needs, but not the environmental spillovers. In any case we have not been notified of any environmental breaches by NEMA’’…….(Agricultural extension officers in the two counties).

The above finding suggest low institutional awareness and fragmented approach, a finding that is consistent with Seidler et al., [6], and Ayers et al., [12], respectively on determinants of adaptation failure. In addition, an extension officer, Machakos county, had this to say:

> ‘‘The farmers have not reported any problems with water sources for irrigation except for one borehole in the neighbourhood that was abandoned after the crops under irrigation started giving extremely low yields and becoming uneconomical to the extent that the farmer abandoned farming. We suspect salinity issues but so far we haven’t verified whether the borehole was unsuitable for irrigation or the abandonment was due to other causes”…..(An Agricultural extension officer, Machakos County).

Analysis of water sample from the above mentioned borehole revealed extremely high salinity and its unsuitability for irrigation in absence of robust mitigation measures suggested by FAO[32] , such as, annual soil testing, mixing of rain and borehole water sources, adequate drainage as well as deep tillage, drainage canals, application of manure in large amounts to improve infiltration rate and/or planting crops with good salt tolerance being instituted. Of great concern among surveyed farmers, was the widespread ignorance about salinity risks from water sources and their mitigation. The observation is reflective of high level of cognitive failure on soil testing as a risk reduction measure among small scale farmers and government agencies in the two counties. Of the surveyed households, majority (about 98%) had not undertaken soil testing though about 10% of the farmers were aware of salinisation risks. Inspite of the awareness being low, there was a gap between awareness and mitigation. Profit maximisation motive and /or risk aversion attitude on adoption of soil testing as a risk reduction measure among informed farmers seem to be the explanation for the gap. The farmers had this to say;

> “The frequent droughts have negatively affected our livelihoods yet our ability to respond to it is heavily constrained as we have low incomes. We thus have embraced irrigation as a saviour. The initial capital to start an individual irrigation project is hard to come by. Unlike in the past when we could go

> hungry whenever droughts occurred, we can now put food on the table with the small irrigation projects that we have. We however did not test soil and water before embarking on irrigated farming. We don't think there are environmental risks other than the problematic pests and diseases that trouble us. If there were environmental risks, we would have heard from some of the extension programmes on radio and the extension officers who rarely visit our farms. In any case we think it could be costly testing the soil and water unless the relevant government agencies provide such services for free''……………… (Farmer FGDs in Kakamega and Machakos counties)

The cognitive failure across individuals and institutions in adaptation planning in the study area reflect the governance gaps about environmental externalities. The pervasiveness of cognition failure, as manifested through low awareness among farmers and government agencies alike, as well as, poor coordination among formal agencies especially agricultural extension services, is indicative of ineffective adaptation planning frameworks in the counties and the country at large.

Fig 8. Farmers undertaking soil testing as a risk reduction measure in Kakamega and Machakos counties, Kenya

Age	No	Yes	Total	% testing soil
20-29	7	0(0)	7	0(0)
30-49	33	1(3)	34	1.54(4.6)
50-59	14	0(2)	14	0(3.1)
60-69	9	0(1)	9	0(1.54)
70 and above	1	0(0)	1	0 (0)
Total	64	1(6)	65	1.54 (9.24)

Source : Authors statistical analysis of survey data. Figures in parentheses(…) indicate those who are aware about risks from water (salinisation risks)

Mu, Kaplan, & Dankers [72], attributes variance between awareness and implementation to risk disposition in terms of profit motives. This may account for the observed negative odds likelihood between risk message dissemination on choice of water source for irrigation. The negative likelihood has profound policy implication and the management of underlying risks, such as, the environmental spillovers. Though the risk reduction focussed climate change Act has potential to address some of the demand-supply needs and production risks, it fails to recognise the negative environmental spillovers. The cognitive failure is reflected in low institutional attention accorded to slow onset disasters in the NAPAs among actors such as the lead and regulatory agencies. For example, salinisation risks were not mentioned nor captured as concerns that need monitoring. The cognitive failure is aptly reflected in the reviewed Environmental Management Plans(EMPs) from a number of the examined Environmental Impact Assessments (EIAs) reports on irrigation in the study sites and nationally where they are not mentioned.

5.0 Conclusions

Poor system integration, as well as, low attention to spillover systems across scale, especially the low attention, to time related integration needs in adaptation planning has potential to exercabate less recognised slow onset disaster risks, such as, salinisation. In absence of a transformative and system approach, failure to identify and internalise the individual and cumulative impacts of the seemingly minor footprints could over time substantially increase land degradation risks and impose costs on the society at large. In this study we explore farmer perception on slow onset disasters and how it constraints transformative adaptation. Ecosystem spillovers which impact society at large (social costs) is explored as a complimentary analytical lens in adaptation policy framing. Specifically, the role of cognition or perception in mobilising peoples' commitment to action over negative environmental externalities, risk belief and mitigation action has been highlighted. The findings suggest that multifaceted biases and failures about the existence and importance of externalities across scale, a critical gap in adaptation planning discourses, is exercabated through low awareness, fragmented approaches and technological biases among actors in adaptation planning.

Though under diverse social-economic contexts education level, farming experience, and information accumulation as human capital components significantly account for adoption of technologies in conventional technology diffusion trajectories, in absence of risk message information, they do not significantly influence risk reduction behaviour concerning environmental spillovers. Since existing adaptation planning frameworks are biased towards use of technology at the expense of environmental footprints, they are more likely to translate to ineffective adaptation planning and contribute to cumulative environmental impacts. The failure by diverse actors across scale to recognise the externalities, as well as, the low institutional awareness constitute cognitive failure with potential to undermine, ecosystems, farmer adaptive capacity and livelihoods in the long run. This could be reversed through system integration which encompasses policy, individual and institutional dynamics, as well as, concomitant focus on environmental, social and economic dimensions of sustainability, resilience building and risk reduction.

Optimising the benefits and concomitant minimisation of maladaptation risks thus require robust adaptation-mitigation-sustainability frameworks that prioritise the mitigation of disaster risks based on broader decision support systems, such as, coordinated adaptation planning across scale and dissemination of risk messages about underlying risks. Transformative adaptation policy framing and information support frameworks have great potential to guide informed decision making and a paradigm shift towards effective adaptation action, learning and mitigation of environmental externalities.This is particularly relevant for slow onset disasters, such as salinisation related land degradation risks, where lack and /or poor knowledge of the consequences of the effect resonates with the narrative of wicked environmental problems and adaptation failure. Electronic and print media could compliment conventional extension strategies in risk information dissemination especially as relates to secondary risks in climate change adaptation.

The main limitation to our study was the hypothetical inclusion of risk message dissemination effect and thus a likely bias of elicited responses. However, climate change in terms of droughts and various communication media are widely known in the study sites with weather shocks occurring at least once every 3-5 years. The respondents were thus highly familiar with climate change issues being investigated. The use of mixed methods to triangulate gathered information as well as in-depth comparative analysis further corrected for any bias.

Author Contributions: V.T.E conceived the basic idea of the study. V.T.E and J.O.O designed the structure of the study. V.T.E wrote while J.O.O revised the manuscript. Both authors approved the final version of manuscript.

Declarations of interest: none

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

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