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Maladaptive Outcomes of Climate Insurance in Agriculture

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Abstract: Agricultural insurance programs are currently being championed by international donors in many developing countries. They are acclaimed as promising instruments for coping with climate risk. However, research on their impacts has mainly focused on economic considerations. Studies on broader social and ecological consequences are sparse and have produced ambiguous and inconclusive results. We address this knowledge deficit by (a) advocating for a holistic view of social-ecological systems and vulnerability when considering insurance impacts; (b) offering a systematic overview highlighting the potential beneficial and adverse effects of 'climate insurance' in agriculture, particularly where programs target intensifying agricultural production; and (c) suggesting preliminary principles for avoiding maladaptive outcomes, including specific recommendations for designing appropriate impact studies and insurance programs. Our synopsis brings together scientific knowledge generated in both developing and developed countries, demonstrating that agricultural insurance programs shape land-use decisions and may generate serious economic, social, and ecological consequences. If insurance is to be an appropriate tool for mitigating the impacts of climate change, it needs to be carefully developed with specific local social-ecological contexts and existing risk coping strategies in mind. Otherwise, it is liable to create long-term maladaptive outcomes and undermine the ability of these systems to reduce vulnerability.

Keywords: index insurance; resilience; climate change adaptation; smallholder agriculture; vulnerability; agroecology

1. 'Climate insurance' in agriculture: a topical issue

Weather risk is an issue of extraordinary socio-economic concern, not least for rural agricultural households in developing countries. This holds especially true in the face of climate change. Governments and international donors currently promote 'climate insurance', which has emerged as an umbrella term for a host of financial mechanisms that make payouts following extreme weather events (cf. Table 1). The G7 'InsuResilience' initiative, for instance, pledged USD 400 million at the Paris climate conference (GIZ, 2015), and the Global Index Insurance Facility has a portfolio of 148 million US dollars (GIIF, 2016).

The global volume of subsidies for novel insurance programs targeting weather risk in agriculture is hard to estimate but has most likely surpassed a billion US dollars. A rough approximation can be made based on the global volume of agricultural insurance premiums, which is estimated at USD 5 billion in emerging markets (SwissRe, 2013). The World Bank estimates that 44 percent of agricultural insurance premiums consist of subsidies (Mahul and Stutley, 2010). Despite the lack of more recent data, these two figures combined suggest an annual volume of subsidies to agricultural insurance (not just index insurance) in emerging markets of at least two billion dollars. This estimate has been corroborated in personal communications with several practitioner experts.

Table 1: Glossary of insurance-related terms

Agricultural insurance	Agricultural insurance has a long history dating back to 18th-century Europe (Smith and Glauber, 2012). Today, it remains largely a developed-country business. Crop insurance may directly cover losses in crops that occur due to natural hazards or, in some cases, insure a farmer against a loss of revenue due to changing prices. Similar programs exist for livestock, fisheries, and forestry.
Climate insurance	An umbrella term to refer to a host of financial mechanisms making payouts following extreme weather events. These include weather index insurance products and sovereign macro-level insurance policies and catastrophe bonds (which act as alternative insurance policies where investors' principal is paid out to the country in case of a natural disaster). While some of these burgeoning insurance programs have covered an entire region (e.g. weather index insurance in Mexico, Fuchs and Wolff, 2011) or even country (e.g. Ethiopia, Hellmuth et al., 2009), many address private households and thus operate on local scales. Although these programs are routinely referred to as 'climate risk insurance,' in the case of agriculture, they are annual policies that technically insure farmers against seasonal weather events and not the occurrence of climate change per se.
Index insurance	In contrast to conventional crop insurance where payouts are explicitly based on measured loss, payouts are triggered by an environmental proxy variable selected as an index. For instance, to insure against drought, an index may be based directly on measured rainfall or on remotely sensed data such as a vegetation index. If the index crosses a predefined threshold in a given season, this triggers payouts to insured farmers. Another increasingly popular trigger is calculated on the basis of measured average crop yields for a specific area ('area-based yield').
Microinsurance	Microinsurance schemes are characterized by relatively small sums insured, and are usually specifically targeted at low-income households.

Technologically innovative insurance programs, particularly 'index insurance' linking payouts to environmental proxy variables rather than measured losses, are heralded as promising strategies for decreasing poverty and improving climate risk management and resilience in developing countries that are heavily dependent on smallholder agriculture. Associated rationales include boosting food security and agricultural productivity (SwissRe, 2013). As donor and government interest in these insurance programs grows, a large number of pilot studies are ongoing worldwide (Karlan et al., 2014; Greatrex et al., 2015; Jensen and Barrett, 2016).

A debate on the social and ecological effects of such insurance programs in agriculture is urgent given the development and climate adaptation funds poised to pour into this sector in the next five years. New subsidies will amount to at least hundreds of millions of dollars, yet the social and ecological ramifications of these policies have thus far been neglected by funders and advocates. Recent scholarly publications have hinted at the possibility of non-adaptive outcomes (Capitanio et al., 2015; Müller and Kreuer, 2016), which may ultimately increase both risks and insurance premiums (Surminski et al., 2016). Donor and practitioner forums have recently begun developing guidelines for assessing the value of index insurance to clients (Stoeffler et al., 2015). A crucial yet neglected corollary of this work is to evaluate insurance's potential maladaptive social-ecological outcomes. Maladaptation refers to outcomes where action taken to reduce vulnerability produces the opposite effect for other systems, sectors or social groups (Barnett and O'Neill, 2013).

Policy-oriented reviews of the impacts of insurance in agriculture (e.g. Miranda and Farrin, 2012; Blampied, 2016; Schickele, 2016) have focused largely on near-term economic effects and practical challenges accompanying the introduction of insurance products in developing countries (Marenya et al., 2014). Studies that have endeavored to investigate the sustainability of such types of insurance have defined sustainability in narrow financial terms (Hazell et al., 2010; Hess, 2009; Smith and Watts, 2009; Wang et al., 2011). Surprisingly few studies have considered the possible effects of agricultural insurance on social relations and ecological features. Research on the topic is scattered across various disciplines, methodologies, and national contexts. Examples of such effects include the expansion of croplands into environmentally sensitive areas (statistical analysis of historical data by Lubowski et al., 2006), a shift towards riskier production choices (randomized experiment by Karlan et al., 2014, which does not consider this shift to be problematic), or a weakening of informal social networks (Boucher and Delpierre, 2014). To our knowledge, no publication has provided an inventory of potential adverse effects of insurance programs on the social-ecological dimensions of local agricultural systems.

Our paper addresses this research deficit by (a) advocating for a holistic view of social-ecological systems and vulnerability when considering insurance impacts; (b) offering a systematic overview highlighting the potential beneficial and adverse effects of 'climate insurance' in agriculture, particularly where programs target intensifying agricultural production; and (c) suggesting preliminary principles for avoiding maladaptive outcomes, including recommendations for designing appropriate impact studies and insurance programs. We include studies of agricultural insurance in OECD countries despite significant differences in social and political-economic contexts, since these experiences provide insights and cautions that should inform the programs being currently piloted or proposed in developing countries.

2. Agricultural insurance in intertwined social-ecological systems

So far, systematic reviews of insurance tend to neglect the importance of a broad social-ecological viewpoint and focus narrowly on economic drivers and outcomes (e.g. Cole et al., 2012, Figure 1.1 on 'Causal mechanism for index insurance'). Figure 1 represents the scale and units of analysis of such studies, which tend to focus on the insurance purchase, production, and consumption decisions of individual producers and the ramifications of such decisions on household income and welfare.

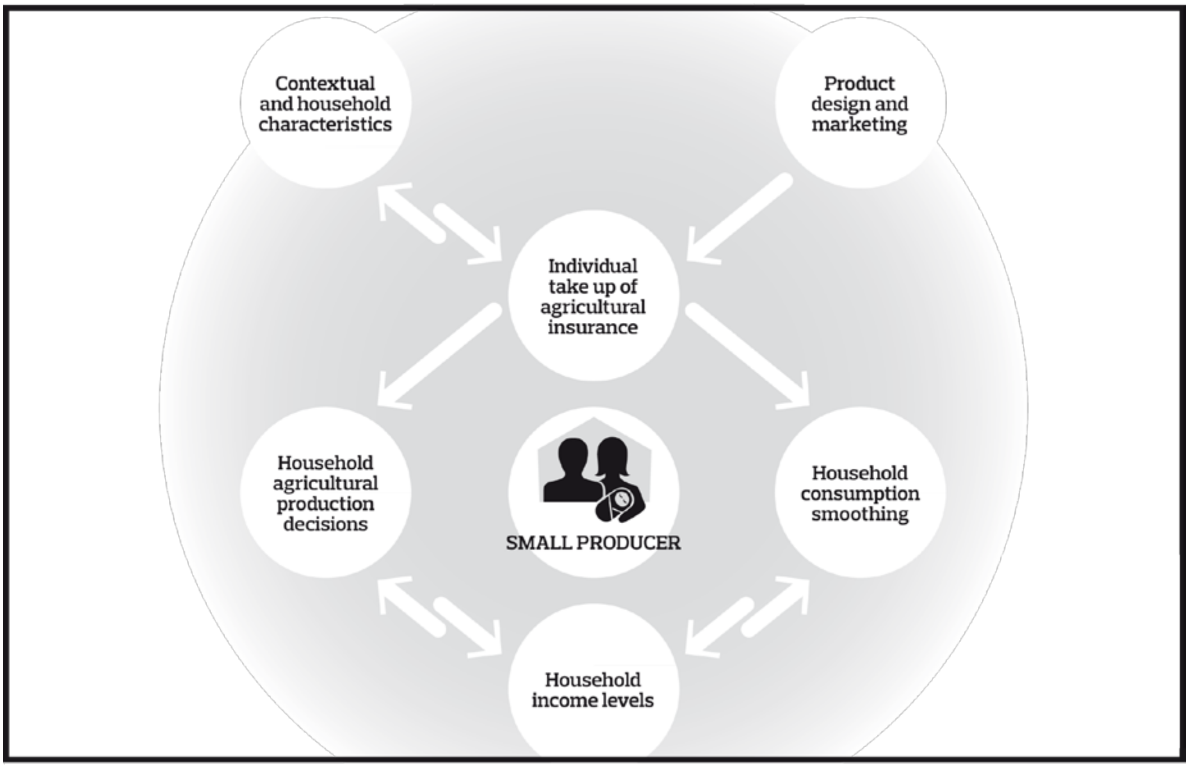

Figure 1: Typical scale and units of analysis of agricultural insurance studies (design by zebraluchs).

Yet accurately assessing the impacts of agricultural insurance projects requires investigating beyond the short-term metrics that can be most easily captured to include effects on contextual vulnerability

(O'Brien et al., 2007), existing social and ecological coping mechanisms, and entitlements used to respond to a range of shocks including weather and market events (Turner et al., 2003; Ribot, 2010).

We argue that it is indispensable to consider the system as a coupled social-ecological system with key features, such as feedbacks and combined effects, that are operative on multiple time scales. Our schematic Figure 1 illustrates this (for a similar attempt with respect to agricultural policies in general see also Lubowski et al., 2006, Fig. 1.1). Rather than just a producer and consumer, we conceptualize a farming household as a set of land users that interact with both a local ecological system and complex social networks, which provide ecosystem services and risk coping / sharing mechanisms, respectively.

Two key features of this social-ecological systems conceptualization are particularly salient for assessing the ultimate adaptive impacts of insurance provision: feedbacks and combined effects.

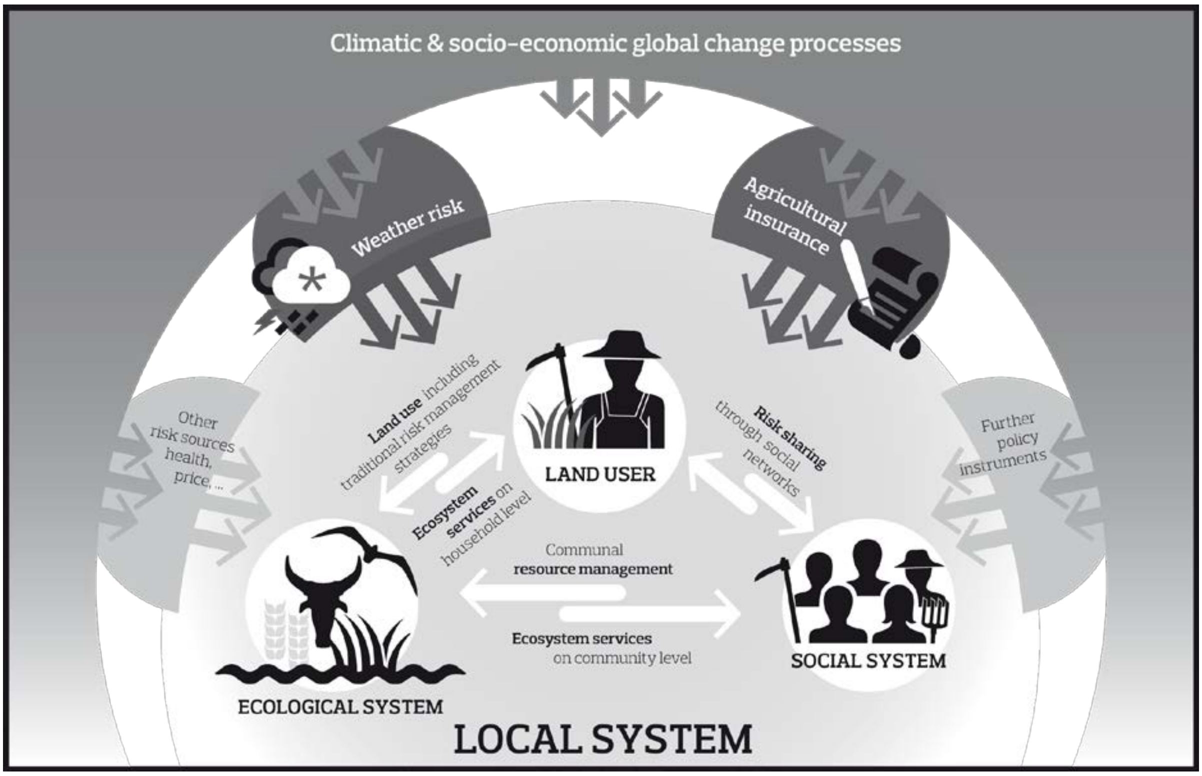

Figure 2: Role of insurance intertwined with other processes in the social-ecological system. White arrows represent feedbacks (design by zebraluchs).

(1) Feedbacks on different scales

Farmers with insurance alter traditional land use strategies to manage climate risk (Sumner and Zulauf, 2012; Smith and Glauber, 2012; Capitanio et al., 2015; see Section 3.1). Responses will differ depending on the type of insurance offered (e.g., insurance for weather risk, yield variation, or revenue fluctuation, see discussion in Finger et al., 2016). Moreover, management strategies will differ from one person to another, depending on available livelihood assets (see Table 2), gender, or attitude towards risk (Lubowski et al., 2006; Peterson, 2012). Furthermore, there is some evidence that land users with insurance may reconsider their engagement in social networks (see Section 3.2).

To the extent that these effects materialize, both can generate crucial feedbacks on environmental and social systems, respectively. On the ecological side, a change of land use strategy affects the flow of ecosystem services (i.e., the benefits people obtain from ecosystems) to an individual farmer (cf. Section 3.1 for further details). These might be positively affected in the short term (high yield from monoculture of insured cash crops), but negatively impacted in the long term (lower pest control and disease resistance). This may have further ramifications for ecosystem service flows at the community level; if, for instance, insurance leads to a decreased use of conservation tillage practices by individual households, services related to water quality valuable for the whole community would be negatively affected (cf. Schoengold et al., 2015). On the social side, if the effectiveness of risk sharing through social networks deteriorates, this could lead to increased vulnerability of the poorest who cannot afford formal insurance (cf. section 3.2).

(2) Combined or contradictory effects with other policy instruments, types of risk, and global change processes in general

Insurance does not act on land users in a vacuum. This can create contradictory effects, since policies supporting food aid or environmental protection are not necessarily harmonized with insurance schemes (cf. Goodwin et al., 2004 on expansion of cropland versus paid land retirement programs in the US). In some cases, agricultural insurance is made a prerequisite for participating in other governmental programs (disaster programs in the US, cf. Smith and Glauber, 2012), but appropriate evaluations of combined effects are not necessarily carried out. An additional concern is the interaction with other types of risk and even a possible displacement of risk from one source to another. For instance, an expansion of cash crops as a consequence of crop insurance might increase farmers' vulnerability to crop price fluctuations in global and local markets. The introduction of insurance may thus accelerate ongoing global processes such as increasing economic integration, exacerbating vulnerable farmers' 'double exposure' to climate change and economic globalization (O'Brien and Leichenko, 2000).

This holistic view on the impact of insurance on social-ecological systems calls for some reflection on the nature and scale of moral hazard. 'Moral hazard' refers to the phenomenon in which people carry out riskier behavior when they are insured, ultimately increasing losses and raising costs for insurers. Because index insurance is based on a pre-specified, exogenous index rather than actual yields, it is frequently asserted that index-based cover reduces the occurrence of moral hazard (cf. Hazell et al., 2010; Clarke and Grenham, 2013; Cole et al., 2014). The crucial point we want to make following from the discussion above is that even index insurance may generate higher – albeit non-monetized – social and ecological costs. Hence the problem of 'moral hazard in a broader sense' persists. However, the costs are not borne by the insurers but by each community as a whole (cf. discussion in Baumgärtner and Quaas, 2009 about negative effects of financial insurance on the natural insurance value of agro-biodiversity and thus on overall welfare).

In summary, adverse social-ecological effects can arise alongside productivity gains or welfare improvements. This possibility should become a significant consideration in the design and monitoring of insurance products and in their subsidy with public funds. As a prerequisite for further study that has been heretofore lacking, we next present a systematic overview of potential social-ecological effects based on current knowledge reflected in theoretical and empirical studies.

3. A systematic overview: Beneficial and adverse effects of agricultural insurance

The starting point for such a systematic overview is the compilation of existing strategies to manage climate risk. This forms the basis for how those strategies will or may change with access to formal insurance, and consequently which beneficial and adverse effects this could precipitate. This prompts crucial questions such as: What type of agriculture are we directly or indirectly promoting through insurance? In what situations are existing risk management strategies insufficient, and could replacing or complementing them with formal insurance be beneficial? Which positive side effects would be missing if existing risk management strategies were no longer applied? And more generally, how can smallholder production be encouraged without doing harm to humans or nonhumans?

We consider effects on all three dimensions of sustainability: economic, ecological and social. We offer, for the first time, a synopsis which brings together scientific knowledge gained both in developing and developed countries and with different approaches, including empirical observations and surveys as well as analytical and simulation models. Where appropriate, we complement the existing arguments with our own hypotheses on impacts of agricultural insurance. Due to the novelty of many of these insurance programs, thorough empirical studies are rare and many statements have to be seen as provisional (Marr et al., 2016).

To structure this overview, we draw on the categorization of five types of livelihood resources (capital) proposed in the widely used Sustainable Livelihoods Framework (Scoones, 1998). This entails conceptualizing five forms of capital as resources upon which households can draw: financial, physical, natural, human, and social capital. We focus on individual agricultural households as pragmatic (yet imperfect) initial units of analysis, because this is often the location of numerous decisions about insurance take-up, land use, and the degree of involvement in other risk management mechanisms. Nevertheless, we take care not to neglect communal resource management decisions with effects at a larger scale. In Section 4.2, we suggest how important intra-household dynamics not represented in the table (particularly those that manifest around gender) might play out.

The altered risk management strategies resulting from the introduction of insurance may have both beneficial and / or adverse effects on specific livelihood resources. Changes in one category of livelihood resources (capital) often propagate to other types of assets as well. We do not suggest that the effects identified are inevitable or necessary consequences, but rather that they are potential outcomes whose materialization will vary by context. They will inevitably vary depending on the *differentia specifica* of the insurance contract design and its relative emphasis on the market development or social protection functions of insurance.

Table 2 provides a condensed version of this overview. The table includes symbols to indicate the respective types of research that have produced each insight (e.g., modeling studies or conjecture without empirical evidence by other authors). The icons thus signal the varying degrees of certainty and generality for each statement on the one hand, and existing research lacunae on the other. Contradictory findings are marked with a symbol (↔); the contradictory outcomes (both observed and theorized) may be a result of responses to differently designed insurance programs (weather index, yield, or revenue-based). Where the arguments are based on empirical evidence, we indicate the respective country names. A more detailed table with further specified case studies and corresponding references can be found in the supplementary material (cf. Table A1). Neither table is meant to be exhaustive, but rather to give a systematic and illustrative overview of the primary features.

- Table 2 -

Table 2 demonstrates that formal insurance may have an impact on all types of livelihood resources. Notably, the observed, modeled and / or hypothesized effects on particular resources sometimes contradict one another (e.g. insurance will increase / decrease fertilizer use).

It bears exploring selected adverse effects on natural and social capital in more detail, and particularly reflecting on the implications of bundling insurance with agricultural inputs, followed by a brief exploration of protection- versus promotion-oriented insurance programs.

3.1. Effects on natural capital

A crucial effect of insurance is related to the increased share of cash crops at the expense of drought-resistant subsistence crops (cf. randomized control experiments in India, Mali, and China: Mobarak and Rosenzweig, 2012; Elabed and Carter, 2015 and Cai, 2015). Additionally, it has been hypothesized that traditional cropping practices which reduced the impact of drought – such as intercropping of crops with different drought tolerances or application of moisture conservation techniques – will be applied less frequently with insurance (Skees et al., 2008). This may reduce the overall resilience of the ecological system by omitting positive effects of intercropping such as improved soil fertility, reduced pest incidence, and increased agrobiodiversity (Lithourgidis et al., 2011).

A second concern is the effect of insurance on the extensive margin – the expansion of cultivated areas into environmentally sensitive marginal lands of lower agricultural value. This topic is controversially debated in the US, whose crop insurance program is the world's largest in premium volume (Smith and Glauber, 2012, p. 363; Claassen et al., 2011; Wu, 1999). The effect of insurance differs depending on physical characteristics and location (significant but modest effect in Goodwin et al., 2004; but with a more likely effect on environmentally sensitive areas such as wetlands, cf. Lubowski et al., 2006). Here, potentially disastrous consequences for water quality, soil erosion, and wildlife populations have been pointed out (LaFrance et al., 2002; Faber et al., 2012; Male, 2014). Partly in response to this, the 2014 Farm Bill re-linked crop insurance to conservation compliance for wetlands in the US (see section 4.3).

Recent studies in developing countries reveal that access to insurance increases riskier production choices such as agrochemical input use (e.g. purchase of fertilizers in a framed field experiment in rural Ethiopia: Hill and Viceisza, 2012, in Ghana: Karlan et al., 2014 or Kenya: Sibiko and Qaim, 2017). The intended effect of such intensification is greater yields; on the other hand, intensive agrochemical use can have negative consequences on ground water, biodiversity, or human health under certain conditions (Matson et al., 1997). This in effect depletes the 'natural insurance' provided by ecosystem services in a diversified farming system (Kremen and Miles, 2012).

Studies from the US disagree on the effect of insurance on the use of fertilizers and pesticides (Horowitz and Lichtenberg, 1993 assume an increased use, Quiggin et al., 1993 a decreased use, see also discussion in Smith and Goodwin, 2013 and Babcock and Hennessy, 1996). The differentiating factor seems to be the specific ratio of input costs to yield improvements: if inputs costs are disproportionately larger than yield gains, then their use with insurance may increase, whereas the opposite may hold where costs are smaller than yield gains (Horowitz and Lichtenberg, 1994). Norton et al., 2016 propose using index insurance as a means to reduce the overuse of harmful pesticides. Yet the explanatory power of these studies from the US is limited, as they are based either on models or on surveys without baselines prior to the introduction of insurance. Furthermore, they may have limited applicability to smallholder agricultural contexts in the developing world, where liquidity constraints may mean farmers are only likely to increase input use with the presence of insurance, regardless of relative yield gains. Here, the aforementioned ongoing randomized control trials (with and without formal insurance) in the developing world may generate important new data.

3.2. Effects on social capital

The presence of formal insurance mechanisms providing post-loss payouts interacts with preexisting methods for risk coping within communities, in particular with the social networks and social norms that households rely upon to cope with asset loss. Individually-purchased insurance may reduce the likelihood that a household contributes to or benefits from such networks, through which a variety of post-loss transfers may be made, including recapitalization, loans, harvest sharing, or providing labor or employment for a household in distress (Boucher and Delpierre, 2014; Platteau, 1991; Coate and Ravallion, 1993). Economists often refer to these arrangements as 'informal insurance' and note that, while such arrangements sometimes work relatively well to protect households against idiosyncratic shocks such as death or animal disease (but see Platteau, 2005), they perform poorly when the entire community experiences a covariate shock such as severe drought (Mobarak and Rosenzweig, 2013). The fact that climate change may increase the frequency of covariate shocks has given further impetus for the development of formal market based agricultural insurance solutions (Collier et al., 2009; Klohn and Strupat, 2013).

Recent econometric studies investigating the effect of index insurance purchase on informal insurance through social networks have yielded contradictory results. Though theory suggests that formal insurance offered to individuals reduces participation in informal arrangements, yielding negative social welfare impacts (Boucher and Delpierre, 2014), some empirical studies find that the provision of formal insurance has strengthened certain informal risk sharing networks in Ethiopia and India (Dercon et al., 2014; Mobarak and Rosenzweig, 2013). Beyond the specific field of agricultural insurance, similar observations have been made for the introduction of formal health insurance in developing-country contexts (e.g., Klohn and Strupat, 2013 for Ghana, Banerjee et al., 2014 for India).

Ultimately, the effects of a formal insurance contract will likely depend on whether it is complementary or duplicative of existing informal arrangements. Where informal networks (such as Ethiopian *iddirs* – burial societies) cover idiosyncratic individual risks, formal weather insurance for group members' covariate drought risk may make informal arrangements more secure and effective. But where a single well-defined risk is already the target of informal arrangements, a formal insurance product may fragment existing networks. A livelihoods framework (Scoones, 1998) would suggest that in either case, a great deal of the strength of risk sharing networks and the impact of formal insurance thereon will depend on communities' social stratification, livelihoods and resource base, and access to institutions and markets. Migration constitutes another risk-management strategy which may be affected by insurance, but as of yet there is little more than speculation about the various pathways through which disaster insurance could influence post-disaster mobility (Clarke and Grenham, 2013). This has remained unexamined in studies of agricultural insurance. Further research that accounts for such particularities is urgently needed.

3.3. Issues related to bundling insurance with inputs

Another series of possible effects derives from the recent trend towards bundling the purchase of insurance with 'value-adding' agricultural inputs and / or agricultural credit. This trend has been driven by the ambition to use insurance programs to actively promote agricultural development (differing from social protection oriented interventions, cf. section 3.4). Bundling with inputs entails packaging an insurance policy with seeds or agrochemicals purchased from an agrodealer (cf. de Nicola, 2012); in some cases, the cost is included in the price of the inputs, while in others the farmer elects to pay a small additional charge to activate coverage. Bundling insurance with credit has been celebrated as a way to improve farmers' access to finance by reducing banks' risk of loaning to weather-exposed clients. Bundling is usually orchestrated through a rural microfinance institution and entails voluntary or mandatory insurance cover linked to an agricultural loan, which may be used to expand production or finance the purchase of inputs.

Probably the most common bundled input to date are 'improved' hybrid seed varieties, which are bred by companies for particular qualities such as yield, or short growth duration. One often-cited and favored model is the Syngenta Foundation's Kilimo Salama rainfall index insurance product, which compensates East African farmers' purchase of hybrid seeds in the event of adverse weather as recorded by a rainfall index. The product, which is bundled with farmers' purchase of seeds at sowing time, has now spun off into a private for-profit model marketed by the ACRE company. As index insurance pilot projects come under pressure to transition from donor funding to financial sustainability, bundling contracts with the purchase of agricultural inputs is often proposed as the only viable way to generate sufficient demand and reach widespread scale with index insurance (Binswanger-Mkhize, 2012).

Though impacts of such product bundles may not be directly mappable in the format of Table 2 above, some reflection on the cumulative effects of their design is warranted. First, the drought tolerance of some hybrid varieties is lower than traditional varieties with correspondingly lower yields (Lipper et al., 2009). In the context of low rates of input use and marginal production conditions, landraces may perform better than improved varieties; drought tolerance of landraces may be in higher demand than improved varieties that promise shorter growing seasons (Lipper et al., 2009). The climatic fragility – and in some cases, water requirements – of hybrid varieties is a major reason that formal weather insurance is a necessary accompaniment to modernized intensive cultivation. Yet especially in an uncertain and changing climate, agrobiodiversity constitutes a key component of small farmers' adaptive capacities and the open, decentralized in situ genetic system that will serve as genetic resources and breeding stocks for the future (Bellon, 2010; Zimmerer, 2010). Farmers' capacity to save seeds is its own form of cultivation and replanting insurance, also maintaining local and regional varieties appropriate to particular elevations and climatic conditions (Hodgkin et al., 2007). Hybrid seeds typically do not reproduce the desired traits in the second generation and thus cannot be saved from one season to the next.

Ironically, if bundling with inputs makes such projects financially 'sustainable', it may also be what makes them socio-ecologically unsustainable. Avoiding the genetic erosion of seed stock depends on explicit maintenance of both cultivars and the social networks through which they circulate (Hodgkin et al., 2007). If the collective maintenance of such practices is weakened, farmers (or the donors and governments who support them) could become especially vulnerable to rising insurance premiums or future termination of coverage in regions where insurers deem losses to be unsustainable (Johnson, 2013; Clarke and Grenham, 2013).

Bundling insurance with credit also implies tradeoffs, generating new vulnerabilities while reducing others. On the one hand, a well-designed insurance contract pays out in case of weather events that damage crops and reduce farmers' ability to repay loans. On the other, loans must be repaid at the time of harvest, so market price volatility for crops poses a new risk not covered by the insurance product. Which risk is qualitatively or quantitatively more significant is context-dependent, but it should never be assumed that bundling insurance with credit is perforce risk-reducing.

3.4. Effects of protection- and promotion-oriented insurance programs

Two different and partly contradictory objectives drive the propagation of agricultural insurance schemes: protection and promotion (cf. Hess, 2009). These map partially onto different development paradigms, prioritizing poverty and inequality reduction versus agricultural growth. The protection-oriented insurance design refers to helping poor agricultural households protect critical livelihood assets and reduce vulnerability to climate shocks by providing a 'safety net' (Barrett et al., 2007). Promotion-oriented insurance products, in contrast, seek to foster agricultural development by increasing household investment in yield-maximizing technologies (Carter et al., 2016). In a similar categorization, Hazell et al., 2010 refer to the two objectives as 'index insurance for disaster relief' versus 'index insurance for development'.

Promotion-oriented insurance design is intended to lead to a change of land use strategies and agricultural practices by improving access to credit and protecting farmers' investments (in particular in improved seeds, fertilizers, and pesticides), enabling the cultivation of cash crops (cf. Dercon and Christiaensen, 2011 which mention lack of insurance causes inefficiency in production choices) or intensifying livestock production (Cai et al., 2015). Another intention may be to motivate farmers to extend the cultivated area in regions where large swathes of land are not considered to be in production.

Research studying the impacts of agricultural insurance in the developing world implicitly assumes that food security and climate risk reduction can be best achieved by increasing food production and household incomes in the near term. This assumption overlooks the troubling fact that new agricultural practices may create substantial externalities at the local, regional and global level (for instance, water pollution resulting from increased pesticide and fertilizer use, cf. Matson et al., 1997, Tilman et al., 2001). Hence, if the socio-ecological impacts of new agricultural practices are accounted for, some 'promotion-oriented' insurance designs may actually undermine the protective function of insurance and may lead to moral hazard problems in a broader sense – resulting in higher social-ecological costs for the whole community (see section 2).

Despite protection-oriented insurance's aims to provide a safety net decreasing agriculturalists' vulnerability, in some cases it may also have net negative consequences for land use and agricultural practices. In pastoralist systems, the introduction of insurance may lead to decreasing mobility and increasing stocking rates, engendering negative effects on ecosystems caused by overgrazing (cf. Bhattacharya and Osgood, 2014; Toth et al., 2014). Assessing and anticipating the impacts of both protection- and promotion-oriented insurance and their side effects requires an awareness of how existing risk management strategies in agriculture may interact with insurance contract design.

4. Implications

The potential for maladaptive impacts on livelihood resources demands we recognize several tensions and incompatibilities within resilience and insurance agendas. After outlining these, we advance a set of principles for the design of more holistic impact evaluations and better-adapted insurance programs.

4.1. Contradictions of resilience

As demonstrated by the moniker recently given the G7's climate insurance initiative, 'InsuResilience', policymakers and the private sector often frame insurance as a critical tool for building climate change resilience (cf. GIZ, 2015) – roughly advancing a lay understanding of resilience as a system's capacity to absorb disturbance and bounce back in the face of shocks (Walker et al., 2006). There are three shortcomings of this framing.

First, identifying resilience or its absence depends on the temporal scale and unit of analysis chosen (Carpenter et al., 2001). As Table 2 demonstrates, there are numerous potential maladaptive outcomes of agricultural insurance that could manifest over longer timescales or larger ecological scales even if short-term household-level impact studies demonstrate year-to-year resilient coping.

Second, on its own, 'resilience' has no normative content; that is to say, it is not self-evidently desirable or undesirable. A resilient system is not necessarily an ecologically healthy nor an equitable one: some of the most ecologically degraded landscapes and most unequal social and political structures are remarkably resilient to perturbation (Cote and Nightingale, 2012, Barrett and Constas, 2014). In the absence of explicit design measures to decrease risk exposure, insurance as a mode of resilience is concerned with *maintaining* a system rather than transforming it, by restoring the exact previous state after each shock (O'Hare et al., 2015, Wrathall et al., 2015).

Third, the assumption that more resilient adaptive measures will be incentivized through market-based insurance price signals is questionable, even if one grants that insured behaviors respond directly to such prices. This is because insurance pricing is a highly imperfect signal which varies according to the international reinsurance market's relative cost of capital and interest rates (Johnson, 2015). Furthermore, technical risk pricing reflects insurers' risk estimates for the near future, not the medium- to longer-term planning horizons that should drive adaptation decisions of concern for development practitioners and government agencies.

In partial acknowledgement of these shortcomings, insurance advocates typically mention that additional risk-reducing measures must be implemented alongside insurance. Yet this discussion often neglects how the intervention will interact with or displace existing and autochthonous agricultural adaptive measures, how new risk-reducing measures will be identified and prioritized, and where they will be sited (see Section 2). The following sections propose initial steps to address these neglected questions.

4.2. Holistic impact assessment studies

Before implementing a pilot study, a set of indicators for evaluating project impacts should be determined – not limited to economic, but also ecological and social indicators (thus extending the set of indicators for impact evaluation found in Bauchet et al., 2014). This should be accompanied by a compilation of existing local risk management strategies and an assessment of their effects. The goal of such a compilation would be not only to establish a baseline against which to assess any future transformation, but also to shed light on fundamental features of the targeted communities such as inter- and intra-household decision-making processes and resource management (cf. Bhattacharya and Osgood, 2014). Repeated participatory resource mapping and community wealth rankings can likewise contribute to this initial inventory taking. Participatory processes could also be designed to anticipate and appraise the potential ecological, social, and economic adverse effects of insurance, including those resulting from changing land use (Stirling et al., 2007). The data gathered with such techniques will be in part qualitative, and the small scope of many pilots may in any case preclude rigorous statistical analysis of quantitative data. Here, there is an important role for developing and refining qualitative research best practices, including for comparative case studies, and for integrating contextually-informed modeling.

Once implemented, pilot projects need to be evaluated across multiple scales to capture cumulative, processual change and cross-scale interactions between dynamic systems, governance arrangements, and power relations (Scoones et al., 2007). Although the number of ex-post impact studies of insurance is growing (cf. Janzen and Carter, 2013; Mobarak and Rosenzweig, 2013; Karlan et al., 2014; Jensen et al., 2014), in most cases, impact evaluations are short-term and oriented around a small number of household indicators. Knowledge on larger effects remains patchy (GIZ, 2016). The extensive multi-year household survey research conducted to assess the impacts of Index-Based Livestock Insurance (IBLI) in northern Kenya and southern Ethiopia (cf. Janzen and Carter, 2013, Jensen et al., 2016, IBLI,

2017) is an exception that proves the rule, as most pilots will not have such large resources and research capacity.

As difficult as monitoring non-economic, cross-scalar, and long-term effects may be, this data will become even more challenging to collect as products are initiated through the private sector rather than through development programming. Thus, the present is a critical moment in which donors can still mandate the collection of a minimal set of indicators to develop an empirical knowledge base on social and ecological impacts as well as economic ones. We suggest the following indicators as a working set (tailored to developing countries). The relevance of each, and the sampling scale, will vary depending on local agricultural context and sources of vulnerability. These include ***biophysical characteristics***: 1) rapid biodiversity assessment, including agrobiodiversity, 2) surface water nutrient loads, quantity, and turbidity, groundwater levels, 3) soil organic carbon, porosity, water content, 4) land use conversion, 5) vegetation status of rangelands; and ***socioeconomic characteristics:*** 6) intensification (inputs per ha), 7) household access to productive resources including water, animals, land, and labor, 8) seed sharing, 9) household indebtedness, 10) child health status, 11) use of / access to networks for assistance, 12) maintenance or loss of existing risk management strategies, and 13) community socio-economic inequality. In practice, a thorough empirical investigation of all items on this list may be difficult to carry out for pilot insurance projects. At the very least, however, an important step forward would be to discuss potential short and long-term impacts on all 13 indicators and decide on their respective priority in a participatory manner.

Evaluations must also consider how impacts are distributed, and the likelihood that programs may have differential impacts within and between households, depending on wealth, gender, and other dimensions of difference (cf. Bauchet et al., 2014). Gendered impacts have been particularly neglected; women and men often control different crops and livestock or are responsible for different agricultural tasks. If insurance leads to switching crops, adopting different cultivation techniques, or changing livestock herd composition, we should anticipate gendered impacts on asset control and labor within households (cf. Gadio and Rakowski, 1999; Padmanabhan, 2007; Kristjanson et al., 2014). These dynamics should be monitored in addition to obvious questions of intra-household control over payouts. Finally, as a complement to ground-based understandings of agricultural practices at the household and village level, remote sensing tools may assist in monitoring human ecological transformations (e.g. Turner, 2003), particularly at the scale of landscape level mosaics and bioregions.

4.3. Recommendations for improved insurance design

Several suggestions regarding an improved elaboration process and better design for future agricultural insurance programs follow from this analysis.

1. Evaluate priorities. Participatory methods should be used to assess priorities for risk reduction. Insurance is not necessarily the most appropriate tool to reduce vulnerability; e.g., constraints on access to resources may be more important in a given setting (McDowell and Hess, 2012). Insurance should also be compared to other financial services such as credit or transfer programs (Quinn et al., 2014) and non-financial risk-coping strategies. The social-ecological context (including the institutional environment, resource distribution, and structural inequalities) must be genuinely appreciated, and local knowledge, needs, and ideas taken seriously (Peterson, 2012), including in the eventuality that a community prioritizes an intervention other than insurance. Nevertheless, increased stakeholder participation alone does not guarantee better socio-ecological outcomes.

2. Encourage diversity. Insurance should be designed to maintain diversity (e.g. of crops, seeds, and strategies) and "should not reduce the farmer's choice set of adaptation strategies' (Skees et al., 2008, p. 24) by advancing crop-specific insurance products that do not cover all crops equally. At the same time, insurance premiums should reflect the higher risk of unsustainable management practices such as monocultures, and incentivize crop diversity. An innovative approach in this direction is the Whole Farm Revenue Program (WFRP) available in the US since 2015, which explicitly acknowledges the lower risk of revenue loss because of farm diversification. Policies include a premium rate discount as well as higher coverage levels for greater amounts of farm diversification (counted in number of commodities produced, cf. USDA, 2016). Although revenue insurance programs are often considered

untenable in the developing world due to record-keeping requirements, index-based contract pricing might also be innovatively designed to encourage diversification.

3. Adapt policies. Policy effects will typically differ from one location to another according to specific features of local environments. Uniform policies for large geographical areas may have locally severe impacts on chemical and physical soil properties that are invisible in aggregated evaluations (Walters et al., 2012). Contract parameters should reflect insureds' own understanding of the boundaries of their climatic zones; for instance, in Northern Kenya, the Index Based Livestock Insurance program reduced the geographical area of some index units in response to pastoralist demands to more closely reflect vegetation conditions in their home grazing territories.

4. Choose the right scale. To avoid a crowding out of social networks, insurance products may be offered on the village or community scale rather than for individual households. This is an admittedly imperfect solution: existing structures of rural inequality mean that not all households are equally exposed to risks (cf. Barrett et al., 2001), and the benefits of payouts may also be unequally distributed.

5. Limit coverage to extremes. Insurance contracts and trigger levels should be consciously designed to avoid crowding out existing risk coping and risk sharing strategies and ecological forms of 'natural insurance' (see 3.1). Accounting for different frequencies and impacts of shocks (Skees et al., 2008, Mechler et al., 2014) and creating contracts that are triggered only by more extreme events can encourage the maintenance of sustainable local risk coping strategies to overcome small and medium shocks (cf. Müller et al., 2011: resting of pastures in rainy years acted as natural insurance and prevented pasture degradation).

6. Tie insurance to ecologically sound strategies. To avoid maladaptation, strategies should contribute to sustainable human development irrespective of climate change risks (Barnett and O'Neill, 2013). Not least, premium subsidies could be granted only under the condition that ecologically beneficial land use strategies are adopted, such as practices promoting sustainable agriculture (cf. Tilman et al., 2002, including investment in education on sustainable farming techniques such as efficient fertilizer application and soil fertility increasing cultivation practices; see also Altieri, 2002 and Tilman et al., 2011). The often-cited HARITA / R4 insurance program carried out in Ethiopia, for instance, incorporates ecological risk reduction activities: through the government-sponsored Productive Safety Net Program that pays citizens for work, farmers can pay insurance premia by investing their labor in terrace maintenance, composting, and tree planting (Peterson, 2012). A similar set of risk-reducing actions has been introduced in R4 programs in Senegal and Malawi. The 2014 US Farm Bill (cf. USDA, 2014) only provides crop insurance subsidies to farmers who do not cultivate converted wetland or highly erodible land without an approved conservation plan.

Yet, conditional programs that incentivize particular kinds of ecological work are not without problems: questions of who should decide on and prioritize the forms of work undertaken and where they should be located (and thus which farmers may benefit most) remain black-boxed. There is a risk of such government / INGO programs imposing interventions poorly suited to the local social or ecological context, or of improvements being captured by local elites. Deliberation, identification, and direct funding of desirable transformations (O'Brien, 2012) are preferable to a 'carrot and stick' approach that uses insurance as an indirect tool to pursue amorphous development or adaptation goals (Wrathall et al., 2015).

5. Conclusion

Despite the welfare gains potentially generated by agricultural insurance for climate risks, the design of such programs requires far more reflection on potential social-ecological side effects. Otherwise, these increasingly popular interventions run the risk of generating climate-maladaptive outcomes over the long term. Looking forward, the economic metrics that have been used to evaluate their impacts are insufficient to capture a multitude of possible ecological and social consequences crossing spatial and temporal scales. Academic research on agricultural insurance should extend beyond economics to fields such as environmental science, geography, and anthropology to more rigorously assess land use changes and interactions within social-ecological systems.

Design and evaluation frameworks should integrate impact assessment of existing forms of 'natural' and informal insurance, such as agricultural biodiversity and social norms of redistribution. Since impacts on these systems may be cumulative or emerge only at some threshold, time frames for evaluation must also be longer than usual economic impact studies – five to ten years is probably a minimal period required for such observations. Given the shorter time scales of typical donor funding, one option may be independently funded impact evaluation studies (cf. a recent call by 3IE, 2016). In addition, forward-looking methods (such as contextually informed modeling) could be employed to generate reasonable projections about the range of possible risk outcomes, updated as social-ecological responses unfold.

We have suggested that the type of 'resilience' that some insurance programs may foster – a return to the status quo or an intensification of input-heavy agriculture - is not a *prima facie* desirable outcome. This has implications for policy and implementation. Current and future 'climate insurance' projects must grapple with the contradictions arising between a development paradigm pursuing agricultural growth through intensification on the one hand (a promotion-oriented approach), and the creation or maintenance of social-ecological conditions for reducing climate vulnerability on the other (a protection-oriented approach). Insurance schemes should be combined with consciously designed programs to invest in and educate about sustainable agricultural techniques. Recent policies linking insurance coverage and subsidies to diverse and ecologically sensitive cultivation, as in the 2014 US Farm Bill, may provide new frameworks for the design of insurance programs in developing countries. This also requires rethinking some of the policy community's accepted wisdom on bundling insurance with inputs, which may make socioecological systems and smallholders more fragile and vulnerable in the face of a changing climate.

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Supplementary material to: Maladaptive Outcomes of Climate Insurance in Agriculture

Table A1: Potential change with insurance, resulting beneficial and adverse effects categorized using the different types of livelihood resources (capital types) of the Sustainable Livelihoods Framework of Scoones, 1998

7. References

3IE, (2016) Agricultural insurance: assessing the impact of programmes targeted at smallholder farmers. Request for proposals. http://www.3ieimpact.org/media/filer_public/2016/06/01/rfp-agri-insurance-tw13.pdf, last accessed, October 28 2016.

Altieri, M.A. (2002) Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems & Environment 93, 1-24.

Babcock, B.A., Hennessy, D.A. (1996) Input Demand under Yield and Revenue Insurance. American Journal of Agricultural Economics 78, 416-427.

Banerjee, A., Duflo, E., Hornbeck, R., (2014) Profit is Not Welfare: Evidence from an Experiment on Bundling Microcredit and Insurance, http://scholar.harvard.edu/files/hornbeck/files/sks_insurance_august2014.pdf, last accessed October 28 2016.

Barnett, J., O'Neill, S.J., (2013) Minimising the risk of maladaptation, Climate Adaptation Futures. John Wiley & Sons, pp. 87-93.

Barrett, C., Barnett, B.J., Carter, M., Chantarat, S., Hansen, J., Mude, A., Osgood, D., Skees, J., Turvey, C., Ward, M.N., (2007) Poverty traps and climate risk: limitations and opportunities of index-based risk financing. Columbia University IRI Technical Report, 07-03.

Barrett, C., Smith, K., Box, P. (2001) Not Necessarily In The Same Boat: Heterogeneous Risk Assessment Among East African Pastoralists. The Journal of Development Studies 37, 1-30.

Barrett, C.B., Constas, M.A. (2014) Toward a theory of resilience for international development applications. Proceedings of the National Academy of Sciences 111, 14625-14630.

Bauchet, J., Dalal, A., Morduch, J., (2014) What can we learn from impact assessments?, in: Radermacher, R., Roth, K. (Eds.), A Practical Guide to Impact Assessments in Microinsurance. Microinsurance Network and Micro Insurance Academy. http://www.microinsurancenetwork.org/groups/practical-guide-impact-assessments-microinsurance. Last accessed November 3 2016, pp. 61-80.

Baumgärtner, S., Quaas, M.F., (2009) Agro-biodiversity as natural insurance and the development of financial insurance markets, in: Kontoleon, A., Pascual, U., Smale, M. (Eds.), Agrobiodiversity, Conservation and Economic Development. Routledge, London, UK, pp. 293-317.

Bellon, M., (2010) Do we need crop landraces for the future? Realizing the global option value of in situ conservation, in: Kontoleon, A., Pascual, U., Smale, M. (Eds.), Agrobiodiversity and Economic Development. Routledge, pp. 51-61.

Bhattacharya, H., Osgood, D. (2014) Weather Index Insurance and Common Property Resources. Agricultural and Resource Economics Review 43, 438-450.

Binswanger-Mkhize, H.P. (2012) Is there too much hype about index-based agricultural insurance? Journal of development studies 48, 187-200.

Blampied, C., (2016) Weathering a Risky Climate: the role of insurance in reducing vulnerability to extreme weather. Report. RESULTS UK.

http://www.results.org.uk/sites/default/files/files/Weathering%20a%20Risky%20Climate.pdf. Last accessed: November 3 2016.

Boucher, S.R., Delpierre, M., (2014) The impact of index-based insurance on informal risk-sharing arrangements, in CEPS/INSTEAD Working Paper (Luxembourg), https://arefiles.ucdavis.edu/uploads/filer_public/26/64/2664c503-96b6-425c-a660-b02bb98a9e1b/boucher_delpierre_dec_2014.pdf, last accessed: November 3 2016.

Cai, H., Chen, Y., Fang, H., Zhou, L.-A. (2015) The Effect of Microinsurance on Economic Activities: Evidence from a Randomized Field Experiment. Review of Economics and Statistics 97, 287-300.

Cai, J., (2015) The Impact of Insurance Provision on Household Production and Financial Decisions. http://econweb.umd.edu/~davis/eventpapers/CaiImpact.pdf. Last accessed: November 3 2016. University of Michigan. October 14, 2014.

Capitanio, F., Adinolfi, F., Santeramo, F.G. (2015) Environmental implications of crop insurance subsidies in Southern Italy. International Journal of Environmental Studies 72, 179-190.

Carpenter, S., Walker, B., Anderies, J.M., Abel, N. (2001) From metaphor to measurement: Resilience of what to what? Ecosystems 4, 765-781.

Carter, M.R., Cheng, L., Sarris, A. (2016) Where and how index insurance can boost the adoption of improved agricultural technologies. Journal of Development Economics 118, 59-71.

Claassen, R., Cooper, J.C., Carriazo, F. (2011) Crop Insurance, Disaster Payments and Land Use Change: The Effect of Sodsaver on Incentives for Grassland Conversion. Journal of Agricultural and Applied Economics 43.

Clarke, D.J., Grenham, D. (2013) Microinsurance and natural disasters: Challenges and options. Environmental Science & Policy 27, 89-98.

Coate, S., Ravallion, M. (1993) Reciprocity without commitment: Characterization and performance of informal insurance arrangements. Journal of Development Economics 40, 1-24.

Cole, S., Bastian, G., Vyas, S., Wendel, C., Stein, D., (2012) The effectiveness of index-based micro-insurance in helping smallholders manage weather-related risks. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Cole, S., Giné, X., Vickery, J., (2014) How Does Risk Management Influence Production Decisions? Evidence from a Field Experiment, Harvard Business School Working Paper, 13-080, September 9, 2014.

Collier, B., Skees, J., Barnett, B. (2009) Weather Index Insurance and Climate Change: Opportunities and Challenges in Lower Income Countries. Geneva Papers on Risk and Insurance-Issues and Practice 34, 401-424.

Cote, M., Nightingale, A.J. (2012) Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. Progress in Human Geography 36, 475-489.

de Nicola, F., (2012) The impact of weather insurance on consumption, investment, and welfare. (October 1, 2012). Available at SSRN: http://dx.doi.org/10.2139/ssrn.2169614. Last accessed: November 3 2016.

Dercon, S., Christiaensen, L. (2011) Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. Journal of Development Economics 96, 159-173.

Dercon, S., Hill, R.V., Clarke, D., Outes-Leon, I., Taffesse, A.S. (2014) Offering rainfall insurance to informal insurance groups: Evidence from a field experiment in Ethiopia. Journal of Development Economics 106, 132-143.

Elabed, G., Carter, M.R., (2015) Ex-ante Impacts of Agricultural Insurance: Evidence from a Field Experiment in Mali. http://www.gdn.int/fullpaper/Paper%20for%20Session%2017-Elabed-Carter-Cotton-Ex-Ante%20Impacts%20of%20Agricultural.....pdf, last accessed: November 3 2016.

Faber, S., Rundquist, S., Male, T., (2012) Plowed Under: How Crop Subsidies Contribute to Massive Habitat Losses (http://static.ewg.org/pdf/plowed_under.pdf, last accessed: November 3 2016).

Finger, R., Möhring, N., Dalhaus, T., Enjolras, G. (2016) The effects of crop insurance on pesticide use. Paper prepared for the 156th EAAE Seminar, Prospects for agricultural insurance in Europe, October 3-4, 2016. Wageningen, The Netherlands.

Fuchs, A., Wolff, H. (2011) Concept and Unintended Consequences of Weather Index Insurance: The Case of Mexico. American Journal of Agricultural Economics 93, 505-511.

Gadio, C.M., Rakowski, C.A. (1999) Farmers' Changing Roles in Thieudeme, Senegal: The Impact of Local and Global Factors on Three Generations of Women. Gender and Society 13, 733-757.

GIIF, (2016) Global Index Insurance Facility: Achievements Report (Phase 1: 2010-2015). Global Index Insurance Facility.

GIZ (2015) Climate Risk Insurance for strengthening climate resilience of poor people in vulnerable countries: A background paper on challenges, ambitions and perspectives. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), commissioned by BMZ. http://www.climate-insurance.org/fileadmin/mcii/pdf/G7_Climate-Risk-Insurance_Background-Paper.pdf, last accessed October 28 2016.

GIZ (2016) Innovations and Emerging Trends in Agricultural Insurance (https://www.giz.de/fachexpertise/downloads/giz-2016-en-innovations_and_emerging_trends-agricultural_insurance.pdf, last accessed: April 28 2017).

Goodwin, B.K., Vandeveer, M.L., Deal, J.L. (2004) An Empirical Analysis of Acreage Effects of Participation in the Federal Crop Insurance Program. American Journal of Agricultural Economics 86, 1058-1077.

Greatrex, H., Hansen, J., Garvin, S., Diro, R., Blakeley, S., M, L.G., KN, R., Osgood, D., (2015) Scaling up index insurance for smallholder farmers: Recent evidence and insights. CCAFS Report No. 14 Copenhagen: CGIAR Research. Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: https://cgspace.cgiar.org/rest/bitstreams/38716/retrieve, last accessed: November 3 2016.

Hazell, P., Anderson, J., Balzer, N., Hastrup Clemmensen, A., Hess, U., Rispoli, F., (2010) The Potential for Scale and Sustainability in Weather Index Insurance for Agriculture and Rural Livelihoods. International Fund for Agricultural Development and World Food Programme. Rome, https://www.ifad.org/documents/10180/32647150-6e8a-41f3-8642-404768cfc99f, last accessed: November 3 2016.

Hellmuth, M.E., Osgood, D.E., Hess, U., Moorhead, A., Bhojwani, H., (2009) Index insurance and climate risk: Prospects for development and disaster management. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, http://lib.riskreductionafrica.org/bitstream/handle/123456789/1069/index%20insurance%20and%20climate%20risk.prospects%20for%20development%20and%20disaster%20management.pdf?sequence=1, last accessed November 3 2016.

Hess, U., Hazell, P., (2009) Innovations In Insuring the Poor. Sustainability and Scalability of Index-Based Insurance for Agriculture and Rural Livelihoods. Focus 17, Brief 5.

Hill, R., Viceisza, A. (2012) A field experiment on the impact of weather shocks and insurance on risky investment. Experimental Economics 15, 341-371.

Hodgkin, T., Rana, R., Tuxill, J., Balma, D., Subedi, A., Mar, I., Karamura, D., Valdivia, R., Colledo, L., Latournerie, L., Sadiki, M., Sawadogo, M., Brown, A., Jarvi, D., (2007) Seed systems and crop genetic diversity in agroecosystems, in: Jarvis, D., C, P., HD, C. (Eds.), Managing Biodiversity in Agricultural Ecosystems. Columbia Univ. Press, New York, pp. 77-119.

Horowitz, J.K., Lichtenberg, E. (1993) Insurance, Moral Hazard and Chemical Use in Agriculture. American Journal of Agricultural Economics 75, 926-935.

Horowitz, J.K., Lichtenberg, E. (1994) Risk-reducing and risk-increasing effects of pesticides. Journal of Agricultural Economics 45, 82-89.

IBLI, (2017) Index Based Livestock Insurance. Project data. http://ibli.ilri.org/publications/, last accessed: Mai 4 2017.

Janzen, S.A., Carter, M.R. (2013) After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection. National Bureau of Economic Research Working Paper Series No. 19702.

Jensen, N., Barrett, C. (2016) Agricultural Index Insurance for Development. Applied Economic Perspectives and Policy ppw022. doi: 10.1093/aepp/ppw022.

Jensen, N.D., Barrett, C.B., Mude, A. (2014) Index Insurance and Cash Transfers: A Comparative Analysis from Northern Kenya (December 16, 2014). Available at SSRN: http://dx.doi.org/10.2139/ssrn.2547660, last accessed: November 3 2016.

Jensen, N.D., Barrett, C.B., Mude, A.G. (2016) Index Insurance Quality and Basis Risk: Evidence from Northern Kenya. American Journal of Agricultural Economics 98, 1450-1469.

Johnson, L. (2013) Index insurance and the articulation of risk-bearing subjects. Environment and Planning A 45, 2663-2681.

Johnson, L. (2015) Catastrophic fixes: cyclical devaluation and accumulation through climate change impacts. Environment and Planning A 47, 2503-2521.

Karlan, D., Osei, R., Osei-Akoto, I., Udry, C. (2014) Agricultural Decisions after Relaxing Credit and Risk Constraints. The Quarterly Journal of Economics 129, 597-652.

Klohn, F., Strupat, C. (2013) Crowding out of Solidarity? – Public Health Insurance versus Informal Transfer Networks in Ghana Ruhr Economic Papers #432.

Kremen, C., Miles, A. (2012) Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs. Ecology and Society 17.

Kristjanson, P., Waters-Bayer, A., Johnson, N., Tipilda, A., Njuki, J., Baltenweck, I., Grace, D., MacMillan, S., (2014) Livestock and women's livelihoods, in: Quisumbing, A.R., Meinzen-Dick, R., Raney, T.L., Croppenstedt, A., Behrman, J.A., Peterman, A. (Eds.), Gender in Agriculture: Closing the Knowledge Gap. Food and Agriculture Organization, Dordrecht, pp. 209-233.

LaFrance, J.T., Shimshack, J.P., Wu, S., (2002) The Environmental Impacts of Subsidized Crop Insurance: Crop Insurance & the Extensive Margin. http://econweb.ucsd.edu/~carsonvs/papers/830.pdf, last accessed: November 3 2016.

Lipper, L., Cavatassi, R., Hopkins, J., (2009) The Role of Crop Genetic Diversity in Coping with Agricultural Production Shocks: Insights from Eastern Ethiopia, in: Kontoleon, A., Pascual, W., Smale, M. (Eds.), Agrobiodiversity, Conservation and Econonomic Development. Routledge, New York, pp. 183-203.

Lithourgidis, A., Dordas, C., Damalas, C., Vlachostergios, D. (2011) Annual intercrops: an alternative pathway for sustainable agriculture. Australian Journal of Crop Science 5, 396.

Lubowski, R., Bucholtz, S., Claassen, R., Roberts, M., Cooper, J., Gueorguieva, A., Johansson, R., (2006) Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy. Economic Research Report 25. U.S. Department of Agriculture, Economic Research Service.

Mahul , O., Stutley, C., (2010) Government Support to Agricultural Insurance: Challenges and Options for Developing Countries. Washington DC: World Bank.

Male, T., (2014) Mutually Insured Destruction How Unchecked Crop Insurance Subsidies Harm the Environment (Defenders of Wildlife, http://www.defenders.org, last accessed: November 3 2016).

Marenya, P., Smith, V.H., Nkonya, E. (2014) Relative Preferences for Soil Conservation Incentives among Smallholder Farmers: Evidence from Malawi. American Journal of Agricultural Economics 96, 690-710.

Marr, A., Winkel, A., van Asseldonk, M., Lensink, R., Bulte, E. (2016) Adoption and impact of index-insurance and credit for smallholder farmers in developing countries: A systematic review. Agricultural Finance Review 76, 94-118.

Matson, P.A., Parton, W.J., Power, A.G., Swift, M.J. (1997) Agricultural Intensification and Ecosystem Properties. Science 277, 504-509.

McDowell, J.Z., Hess, J.J. (2012) Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. Global Environmental Change 22, 342-352.

Mechler, R., Bouwer, L.M., Linnerooth-Bayer, J., Hochrainer-Stigler, S., Aerts, J.C.J.H., Surminski, S., Williges, K. (2014) Managing unnatural disaster risk from climate extremes. Nature Clim. Change 4, 235-237.

Miranda, M.J., Farrin, K. (2012) Index Insurance for Developing Countries. Applied Economic Perspectives and Policy 34, 391-427.

Mobarak, A.M., Rosenzweig, M., (2012) Selling Formal Insurance to the Informally Insured.

Mobarak, A.M., Rosenzweig, M.R. (2013) Informal Risk Sharing, Index Insurance, and Risk Taking in Developing Countries. American Economic Review 103, 375-380.

Müller, B., Kreuer, D. (2016) Ecologists Should Care about Insurance, too. Trends in Ecology & Evolution 31, 1-2.

Müller, B., Quaas, M.F., Frank, K., Baumgärtner, S. (2011) Pitfalls and Potential of Institutional Change: Rain-Index Insurance and the Sustainability of Rangeland Management. Ecological Economics 70, 2137-2144.

Norton, M., van Sprundel, G.-J., Turvey, C.G., Meuwissen, M.P.M. (2016) Applying weather index insurance to agricultural pest and disease risks. International Journal of Pest Management, 1-10.

O'Brien, K. (2012) Global environmental change II: From adaptation to deliberate transformation. Progress in Human Geography 36, 667–676.

O'Brien, K., Eriksen, S., Nygaard, L.P., Schjolden, A.N.E. (2007) Why different interpretations of vulnerability matter in climate change discourses. Climate Policy 7, 73-88.

O'Brien, K.L., Leichenko, R.M. (2000) Double exposure: assessing the impacts of climate change within the context of economic globalization. Global Environmental Change 10, 221-232.

O'Hare, P., White, I., Connelly, A. (2015) Insurance as maladaptation: Resilience and the 'business as usual' paradox. Environment and Planning C: Government and Policy 0, 1-19.

Padmanabhan, M.A. (2007) The making and unmaking of gendered crops in northern Ghana. Singapore Journal of Tropical Geography 28, 57-70.

Peterson, N.D. (2012) Developing Climate Adaptation: The Intersection of Climate Research and Development Programmes in Index Insurance. Development and Change 43, 557-584.

Platteau, J.-P., (1991) Traditional systems of social security and hunger insurance: Past achievements and modern challenges, in: Ahmad, E., Drèze, J., Hills, E., Sen, A. (Eds.), Social security in developing countries. Oxford University Press, Oxford.

Platteau, J.P., (2005) The gradual erosion of the social security function of customary land tenure arrangements in lineage-based societies in: Dercon, S. (Ed.), Insurance against poverty. Oxford University Press, Oxford, pp. 247-278.

Quiggin, J.C., Karagiannis, G., Stanton, J. (1993) Crop Insurance and Crop Production: An Empirical Study of Moral Hazard and Adverse Selection. Australian Journal of Agricultural Economics 37, 95-113.

Quinn, S., Dercon, S., Matul, M., (2014) Why and how does impact happen?, in: Radermacher, R., Roth, K. (Eds.), A Practical Guide to Impact Assessments in Microinsurance. Microinsurance Network and Micro Insurance Academy. http://www.microinsurancenetwork.org/groups/practical-guide-impact-assessments-microinsurance. Last accessed November 3 2016, pp. 41-60.

Ribot, J., (2010) Vulnerability does not fall from the sky: toward multiscale, pro-poor climate policy, in: Mearns, R., Norton, A. (Eds.), Social dimensions of climate change: Equity and vulnerability in a warming world. World Bank, Washington, pp. 47-74.

Schickele, A., (2016) Make it Rain. J-PAL, CEGA, and ATAI Policy Bulletin. Cambridge, MA: Abdul Latif Jameel Poverty Action Lab, Center for Effective Global Action, and Agricultural Technology Adoption

Initiative. https://www.poverty-action.org/sites/default/files/publications/Make-it-Rain-Policy-Bulletin.pdf, last accessed: November 3 2016.

Schoengold, K., Ding, Y., Headlee, R. (2015) The Impact of AD HOC Disaster and Crop Insurance Programs on the Use of Risk-Reducing Conservation Tillage Practices. American Journal of Agricultural Economics 97, 897-919.

Scoones, I., (1998) Sustainable Rural Livelihoods: A Framework for Analysis. IDS Working Papers 72.

Scoones, I., Leach, M., Smith, A., Stagl, S., Stirling, A., Thompson, J., (2007) Dynamic Systems and the Challenge of Sustainability, STEPS Working Paper 1, Brighton: STEPS Centre.

Sibiko, K.W., Qaim, M., (2017) Weather index insurance, agricultural input use, and crop productivity in Kenya, GlobalFood Discussion Papers 94, http://hdl.handle.net/10419/156699. Last accessed: April 29 2017.

Skees, J., Barnett, B., Collier, B., (2008) Agricultural Insurance: Background and Context for Climate Adaptation Discussions’. Paper presented at the OECD Expert Workshop on Economic Aspects of Adaptation, Paris (7–8 April). (http://www.risk-award.org/dms/MRS/Documents/Microinsurance/MIC_Agriculture_Bibliography/20080821_SkeesBarnettCollierOECDPaper.pdf, last accessed: November 3 2016).

Smith, V.H., Glauber, J.W. (2012) Agricultural Insurance in Developed Countries: Where Have We Been and Where Are We Going? Applied Economic Perspectives and Policy 34, 363-390.

Smith, V.H., Goodwin, B.K., (2013) The Environmental Consequences of Subsidized Risk Management and Disaster Assistance Programs, in: Rausser, G.C. (Ed.), Annual Review of Resource Economics, Vol 5, pp. 35-60.

Smith, V.H., Watts, M., (2009) Index Based Agricultural Insurance in Developing Countries: Feasibility, Scalability and Sustainability. Working Paper, Bill and Melinda Gates Foundation. https://www.agriskmanagementforum.org/sites/agriskmanagementforum.org/files/Documents/vsmith-index-insurance.pdfm, last accessed: November 3 2016.

Stirling, A., Leach, M., Mehta, L., Scoones, I., Smith, A., Stagl, S., Thompson, J., (2007) Empowering designs: towards more progressive appraisal of sustainability. Working Paper. Centre for Social, Technological and Environmental Pathways to Sustainability (STEPS), Institute of Development Studies.

Stoeffler, Q., Barré, T., Carter, M.R., (2015) Measuring Index Insurance Quality. I4 BASIS Brief, 2015-1.

Sumner, D.A., Zulauf, C.R., (2012) Economic and Environmental Effects of Agricultural Insurance Programs. Council on Food, Agricultural, and Resource Economics (C-FARE), C-FARE Report No 156622 (http://ageconsearch.umn.edu/bitstream/156622/2/Sumner-Zulauf_Final.pdf, last accessed: November 3 2016).

Surminski, S., Bouwer, L.M., Linnerooth-Bayer, J. (2016) How insurance can support climate resilience. Nature Clim. Change 6, 333-334.

SwissRe (2013) Partnering for food security in emerging markets. sigma 1/2013 (Swiss Reinsurance, Zurich).

Tilman, D., Balzer, C., Hill, J., Befort, B.L. (2011) Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences 108, 20260-20264.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S. (2002) Agricultural sustainability and intensive production practices. Nature 418, 671-677.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D., Swackhamer, D. (2001) Forecasting Agriculturally Driven Global Environmental Change. Science 292, 281-284.

Toth, R., Barrett, C., Bernstein, R., Clark, P., Gomes, C., Mohamed, S., Mude, A., Taddesse, B., (2014) Productive Spillovers of the Take-up of Index-Based Livestock Insurance. Working Paper. August 2014. http://ageconsearch.umn.edu/bitstream/172441/2/2014%20June%2011%20ProductiveSpilloversIBLI.pdf, last accessed: November 3 2016.

Turner, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A. (2003) A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America 100, 8074-8079.

Turner, M.D. (2003) Methodological Reflections on the Use of Remote Sensing and Geographic Information Science in Human Ecological Research. Human Ecology 31, 255-279.

USDA, (2014) Highly Erodible Land Conservation & Wetland Conservation Compliance For Crop Insurance Participants (http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1263444&ext=pdf), last accessed: November 3 2016.

USDA, (2016) A Risk Management Agency Fact Sheet: Whole-Farm Revenue Protection. http://www.rma.usda.gov/pubs/rme/wfrpfactsheet.pdf (last accessed: November 3 2016).

Walker, B.H., Gunderson, L.H., Kinzig, A.P., Folke, C., Carpenter, S.R., Schultz, L. (2006) A Handful of Heuristics and Some Propositions for Understanding Resilience in Social-Ecological Systems. Ecology and Society 11.

Walters, C.G., Shumway, C.R., Chouinard, H.H., Wandschneider, P.R. (2012) Crop Insurance, Land Allocation, and the Environment. Journal of Agricultural and Resource Economics 37.

Wang, M., Shi, P., Ye, T., Liu, M., Zhou, M. (2011) Agriculture insurance in China: History, experience, and lessons learned. International Journal of Disaster Risk Science 2, 10-22.

Wrathall, D.J., Oliver-Smith, A., Fekete, A., Gencer, E., Reyes, M.L., Sakdapolrak, P. (2015) Problematising loss and damage. International Journal of Global Warming 8, 274-294.

Wu, J.J. (1999) Crop Insurance, Acreage Decisions, and Nonpoint-Source Pollution. American Journal of Agricultural Economics 81, 305-320.

Zimmerer, K.S. (2010) Biological Diversity in Agriculture and Global Change. Annual Review of Environment and Resources 35, 137-166.

Table 2: Existing risk management strategies without insurance, potential change with 'climate insurance' in agriculture, and potential beneficial and adverse effects categorized using the different types of livelihood resources (capital types) of the Sustainable Livelihoods Framework

	Risk management strategy without insurance	Potential change after insurance introduction	Potential beneficial effects	Potential adverse effects
Financial Capital	Savings (self-insurance) and liquidity	• Quick payouts • Upfront liquidity reduced for premium payments	• Income disposable for health and education ✦ • Post-event liquidity increased	Food price hikes resulting from increased liquidity might affect non-farming households in rural areas where only farming households receive payouts ✦ Mexico
	Credit	• Better access 💻 Peru • Higher take-up 📋 China	Increased access to and investment in technologies	• Unsustainable debt levels • Debt treadmill and dependence on insurance lead insurers to exploit a captive market
Physical Capital	Use and maintenance of local seed varieties, seed saving, seed sharing 👀 Ethiopia	Shift to higher return but riskier improved varieties 👀 Kenya, Switzerland, France 💻	Productivity gains 💻	• Dependence on market seed supply chains • Complementary inputs required for improved varieties • Loss of agrobiodiversity as form of insurance 👀 Ethiopia 💻 ✦
	Use of agrochemicals (pesticides, fertilizers) ⟷	Increased chemical inputs 📋 Ethiopia, Ghana, 💻 Italy 👀 United States, Switzerland, France, Kenya	• Productivity gains ✦ • Less labor force needed	• Water pollution 💻 👀 United States • Biodiversity loss 📋 France
		Fewer chemical inputs 👀 ✦ United States (cf. main text 3.1)	Reduced water pollution	Productivity losses
Natural Capital	***Arable Farming***			
	Diversified farming systems: Multiple/sequential cropping systems, intercropping of crops with different drought tolerances ✦ 👀	Increased share of more productive & risky crops 📋 China, Ghana, India, Mali	Higher returns	• Exposure to market fluctuations • Increased demand for fertilizers, pesticides (involves damages, see above) 📋 United Kingdom • Less nitrogen available for second crops, reduced pest control, lower soil cover ✦ • Soil erosion, decreased carbon sequestration ✦ 📋 Brazil • Functional biodiversity loss ✦
	No crop cultivation in risky environments	Expansion of cultivation into marginal (wet) lands 👀 United States	Economic gains	Negative consequences on water quality, soil erosion, biodiversity ✦
	Traditional strategies for efficient (communal) water use, irrigation systems 👀 ✦ Ethiopia, Mexico, United States	• Changing tillage practices 👀 United States • Neglect of infrastructure (if insurance covers rainfed agriculture only) ✦	Less labor effort needed	• Irrigation infrastructure and institutions difficult to rebuild once collapsed • With damaged infrastructure: decreased buffering capacities for variable precipitation
	Livestock Systems			
	Keeping of drought resistant animal species; mixture of species	Change to profitable livestock species	Higher returns	Exposure to domestic / world market fluctuations
	Mobility (to deal with fluctuating forage availability)	Less mobile livestock system 📋 Ethiopia	Labor force can be used for other tasks (only if demand exists)	Pasture degradation
	Herd size as precautionary savings 👀 Ethiopia; livestock sales after shock 📋 Kenya ⟷	Destocking ✦ 💻	Relief of the ecological system	
		Not forced to sell in times of shock, higher herd accumulation 📋 China, Ethiopia, Kenya 👀 Ethiopia	Short term economic benefit 💻	Pasture degradation
	Resting of pastures for droughts 👀 Namibia	No / less resting of pastures 💻	Short term economic benefit	Degrading pasture state in the long term 💻
Human Capital	Diversification of activities 👀	Focus on single activity 📋 Ghana	Productivity gains	Less risk spreading ✦
	Reliance on household labor	Hiring of more wage labor 📋 India	Increased income for landless laborers	
	Reduction of consumption	No reduction of consumption 💻 West Africa 📋 Kenya	Health improvements	

	Risk management strategy without insurance	Potential change after insurance introduction	Potential beneficial effects	Potential adverse effects
Social Capital	Transfers via informal social networks ↔	More money to support others 📋 Mexico	• Decreasing poverty 📋 Mexico • Index and informal insurance work as complements to reduce risk 📋 Ethiopia, India	
		• Crowding out of informal social networks 💻 Mexico 💻 📋 China 👀 Ethiopia • Reduced risk sharing with uninsured households 💻 ✦ (for both points, cf. discussion in main text 3.2)		Increasing inequality and poverty 📋 💻 Philippines
	Claims and entitlements: price and income support programs, disaster assistance payouts		• Farmers: less reliance on government support • Government: more efficient spending than ex post assistance ✦	Dependence on private insurance mechanisms

Types of evidence:

👀 Empirical observations (surveys, interviews, statistical analyses)
📋 Field / lab experiments
💻 Simulation studies / Analytical models
✦ Reviews and conjecture of others
↔ Contradictory results
No symbol: Own conjecture

Remarks: Adverse effects occur mainly over longer time scales. Columns 4 and 5 include studies from other contexts that investigate impacts following from changes listed in column 3; not all of these were necessarily associated with the introduction of insurance.

Table A1: Existing risk management strategies without insurance, potential change with 'climate insurance' in agriculture, and potential beneficial and adverse effects categorized using the different types of livelihood resources (capital types) of the Sustainable Livelihoods Framework; referenced and more detailed than Table 1.

		Risk management strategy without insurance	**Potential change after insurance introduction**	**Potential beneficial effects**	**Potential adverse effects**
Financial Capital	Savings (self-insurance) and liquidity	Precautionary savings, gone in case of shock (Quinn et al., 2014 ✦)	Quick payouts Upfront liquidity reduced for premium payments Precautionary savings less critical for weather shocks	More income disposable for other types of shocks (e.g. health) and education (Quinn et al., 2014) ✦ Post-event liquidity increased	Food price hikes resulting from increased liquidity might affect non-farming households in rural areas where only farming households receive payouts (Fuchs and Wolff, 2011 ✦ for Mexico)
	Credit	Limited access (cf. Carter et al., 2007 ✦)	Better access (cf. simulation study of Carter et al., 2007 using Peruvian data 💻) Higher take up of credits (Cai, 2015 randomized experiment on tobacco production in China 📋)	Increased access to and investment in new agricultural technologies	Potential for unsustainable levels of agricultural indebtedness; debt treadmill and insurance supply constraints and exclusivity arrangements could create a "captive market" where insurers can command higher premiums
Physical Capital	Seed varieties	Use and maintenance of local seed varieties, seed saving and seed sharing (Hodgkin et al., 2007) 👀 (own observation in Ethiopia)	Shift to higher return but riskier improved varieties (de Nicola, 2012, using a stochastic dynamic model) 💻 Land use allocation to more intensive crops in France and Switzerland (Finger et al., 2016) 👀 Higher use of improved seeds, survey data from Kenya (Sibiko and Qaim, 2017) 👀	Productivity gains (de Nicola, 2012) 💻	Dependence on market seed supply chains Complementary inputs required to realize yield gains of improved varieties Loss of agrobiodiversity as form of insurance (Baumgärtner and Quaas, 2009 💻, Zimmerer, 2010 ✦, Lipper et al., 2009 👀 for Ethiopia)

		Risk management strategy without insurance	**Potential change after insurance introduction**	**Potential beneficial effects**	**Potential adverse effects**
	Use of agrochemicals (pesticides and fertilizers) ⟷	Depending on whether inputs are risk increasing or risk reducing (i.e. increasing / reducing probability of low profits): (i) Inputs are risk-increasing Little usage (Dercon and Christiaensen, 2011 fertilizer usage in Ethiopia 👀) (ii) Inputs are risk-reducing Higher usage of pesticides and fertilizers than without insurance (cf. Smith and Goodwin, 1996; Babcock and Hennessy, 1996)	(i) Inputs are risk-increasing: Increased input usage (Karlan et al., 2014 increased use of fertilizers and renting of tractors for land preparation in randomized experiment amongst Maize farmers in Ghana 📋 Hill and Viceisza, 2012 increased fertilizer usage in Ethiopia using a framed (field) game experiment 📋 Higher use of chemical fertilizer, survey data from Kenya (Sibiko and Qaim, 2017) 👀 Fungicide use positively correlated with insurance use in Switzerland and France Finger et al., 2016 👀 Capitanio et al., 2015 increased fertilizer usage in Italy 💻 Stuart et al., 2014 enrollment in yield insurance program discourages reduced use of fertilizers 👀 United States) (ii) Inputs risk-reducing: Fewer chemical inputs due to moral hazard effects (Smith and Goodwin, 1996) 👀 or appropriate insurance design (Norton et al., 2016) ✦ United States	(i) Productivity gains (Hill and Viceisza, 2012 ✦) Less labor force needed (positive)/ less employment opportunities (negative) (ii) Reduction in water pollution	(i) Damages related to production and use of fertilizers/pesticides: Negative effects on (ground) water quality (cf. Wu, 1999 💻 👀 United States) Human health (Normile, 2013) Animal diversity (Henry et al., 2012 📋 for bees in France) Sensitive to price changes (ii) Productivity losses (Smith and Goodwin, 1996)

		Risk management strategy without insurance	Potential change after insurance introduction	Potential beneficial effects	Potential adverse effects
Natural Capital	***Arable farming***				
	(Temporal and spatial) composition of cultivated plants	Diversifying crop choice: Multiple/sequential cropping systems to avoid complete crop failure (cf. Lin, 2011 ✦; Waha et al., 2013 ✦; Tengö and Belfrage, 2004 👀); ✦Intercropping of crops with different drought tolerances (Lithourgidis et al., 2011 ✦; Cole et al., 2014 ✦; Fuchs and Wolff, 2011 👀)	Increased share of more productive & risky (crop) choices (cf. Mobarak and Rosenzweig, 2012: randomized experiment in India: choice of rice variety higher yielded, but less-drought resistant; 📋 Elabed and Carter, 2015 randomized experiment on extension of cash crop cotton in Mali; 📋 Cai, 2015 randomized experiment: Effect on share of tobacco production in China; 📋 Cole et al., 2014: Randomized control experiment: Change from subsistence (sorghum, grams) to cash crop (castor and groundnut, two rain fed oilseeds, paddy) in India; 📋 Karlan et al., 2014 shift from drought resistant Mango cultivation to Maize, Ghana by a randomized experiment 📋)	Higher returns	**Economic:** Households are more vulnerable to changing prices for cash crops → new exposure to world market risks, trade arrangements/negotiations (Peterson, 2012 ✦); Bundling with inputs: Dependence on insurance to maintain this livelihood strategy and repay debt, vulnerability to premium increases **Ecological:** Monoculture/sole cropping→ without multiple/sequential cropping systems: less nitrogen available for second crops, reduced pest control and lower soil cover (review Lithourgidis et al., 2011, Waha et al., 2013, Lin, 2011 all ✦) → (a) Increased demand for fertilizers, pesticides (involves damages, see above), otherwise reduced yields (Berzsenyi et al., 2000 📋 United Kingdom), (b) Danger of soil erosion, decreased carbon sequestration (Tilman et al., 2002 ✦, Pimentel et al., 1995 ✦, Corbeels et al., 2016) 📋 Brazil (c) Less biodiversity of insects, birds (Vickery et al., 2004✦) (d) Reduction in water use efficiency → Higher economic and ecological costs
		No crop cultivation in unproductive risky environments	Increase of crop cultivation in marginal (wet) land in US (significant but modest cf. Goodwin et al., 2004 👀, but likely affecting environmental sensitive areas Lubowski et al., 2006, study on whole US 👀)	Economic gains	Negative consequences on water quality, soil erosion, biodiversity (LaFrance et al., 2002, Faber et al., 2012, Male, 2014; Goodwin and Smith, 2003; Zimmerer, 2010) ✦
	Application of traditional strategies for efficient (communal) water use	In situ moisture conservation measures (such as bunds, furrows and irrigation), water harvesting, minimum tillage (Cole et al., 2014 ✦, Kassie et al., 2013 in Ethiopia 👀, Ding et al., 2009, US 👀)	Ambivalent effects in a US study (increased use of no-tillage practices and decreased use of other conservative tillage practices, Schoengold et al., 2015 US 👀)		**Social/institutional:** Infrastructure and governance institutions difficult to rebuild **Ecological:** increased topsoil run-off without conservative tillage practices (cf. Tilman et al., 2002)

		Risk management strategy without insurance	Potential change after insurance introduction	Potential beneficial effects	Potential adverse effects
		Development and maintenance of irrigation systems in rain-fed agriculture (Fuchs and Wolff, 2011 for Mexico 👀 where farmers are insured only on non-irrigated land)	Neglect (if insurance covers rainfed agriculture only)	Less labor effort needed	Irrigation infrastructure difficult to rebuild once collapsed; With damaged infrastructure: decreased buffering capacities for variable precipitation
	Pastoralism / Mixed farming (livestock and crop)				
	Herd composition	Keeping of drought resistant animals species; Mixture of species	Change to more profitable livestock species ("cash cows")	Higher returns	Exposure to domestic/world market fluctuations
	Movement strategies	Mobility as key strategy to deal with spatial and temporal fluctuating forage availability, reciprocal arrangements between spatially dispersed communities (cf. review in Fernandez-Gimenez and Le Febre, 2006)	Less mobile livestock system (Toth et al., 2014 in Ethiopia 📋)	Labor force can be used for other tasks (only if demand exists)	Higher grazing pressure → danger of pasture degradation Sedentarization and "dropping out" of pastoralism → negative health outcomes and rising unemployed labor in towns (Little et al., 2008; Fratkin and Roth, 2005 👀 for Northern Kenya) / improved health care access 👀 own observation Kreuer in Morocco
	Herd size ⟷	Lower herd size after shock: household is forced to sell productive asset to smooth consumption (cf. Janzen and Carter, 2013 📋 in Kenya)	Households are not forced to sell productive asset in times of shocks (cf. Janzen and Carter, 2013: randomized experiment in Kenya 📋, Peterson, 2012 Ethiopia 👀)	Short term economic benefit through higher herd size (termed "economic effect" in Bhattacharya and Osgood, 2014 💻)	Higher grazing pressure → danger of pasture degradation
		Herd size as precautionary savings (Peterson, 2012 Ethiopia 👀)	Insurance may lead to destocking if herd accumulation served as precautionary savings (mentioned as one possible hypothesis in Toth et al., 2014) ✦ Reduction of herd size to pay the insurance premium (see substitution effect in Bhattacharya and Osgood, 2014 in an analytical model 💻)	Relief of the ecological system	
			Insurance may lead to higher herd accumulation because attractiveness of livestock raising increases due to lower risk (randomized experiment in Toth et al., 2014 in Ethiopia). 📋		Higher grazing pressure → danger of pasture degradation

		Risk management strategy without insurance	**Potential change after insurance introduction**	**Potential beneficial effects**	**Potential adverse effects**
	Resting	Resting of reserves for droughts (Müller et al., 2007 👀 in Namibia)	No/less resting of pastures necessary (Müller et al., 2011 💻) Mechanisms behind this: a) Without fodder markets: risk averse farmer can use insurance money to smooth income and does not need the rested land as sort of “natural insurance” b) With fodder markets: Insurance money can be used to buy fodder hence reserves are not necessary	Short term economic benefit through higher herd size	**Ecological:** Degrading pasture state in the long-term (Müller et al., 2011 using a modelling study). Consequently negative economic effects in the long-term. 💻
	Intensive livestock system				
	Herd size		Cf. Cai et al., 2015 in a randomized experiment: Increase of sow production in China 📋	Productivity gains	
Human Capital	Labor application	Diversification of activities (Peterson, 2012 👀)	Focus on single activity (cf. randomized experiment Karlan et al., 2014 in Ghana reduction of non-farm labor) 📋	Productivity gains	less risk spreading, reduced off-farm income (Fuchs and Wolff, 2011) ✦
	Hiring of wage labor		Insured farmers hire more wage labor (cf. Mobarak and Rosenzweig, 2013 field experiments in India) 📋	Increased income for landless → reduction of temporary migration	
	Health	Reduction of consumption (implying adverse health effects)	No reduction of consumption (cf. de Nicola, 2015 using a stochastic dynamic model 💻 and data from West Africa; cf. Janzen and Carter, 2013 randomized experiment on pastoralists in Kenya 📋)	Health improvements in particular for children and thus of long-term relevance	
Social Capital	Informal social networks ↔	Informal social networks with cash or in-kind transfers or transfer of a breeding cow (cf. Santos and Barrett, 2011), but covariate losses have less devastating impact on whole communities (Chantarat et al., 2013)	Insured people have more money to support others → decreasing poverty (cf. Angelucci and De Giorgi, 2009: Randomized experiment on effect of cash transfers on informal safety nets in Mexico) 📋	Decreasing poverty (Angelucci and De Giorgi, 2009 for Mexico) 📋 Index insurance and informal insurance can be complements in the presence of basis risk (cf. Dercon et al., 2014 which offer index insurance to risk sharing groups in a field experiment in Ethiopia, Mobarak and Rosenzweig, 2013 for India) 📋	

		Risk management strategy without insurance	Potential change after insurance introduction	Potential beneficial effects	Potential adverse effects
			Formal insurance may crowd out informal social network transfers (e.g. modelling study by Attanasio and Ríos-Rull, 2000 using Mexican data); 💻 Boucher and Delpierre, 2014 using a mathematical model of formal insurance; 💻 Lin et al., 2014 using mathematical model and laboratory experiment in China 📋, 💻; Empirical study of crowding out of informal safety nets by food aid Dercon and Krishnan, 2003 in Ethiopia 👀; Less solidarity with uninsured households, Quinn et al., 2014 ✦ (cf. discussion in main text 3.2)		Increasing inequality/poverty (Landmann et al., 2012, field lab study from Philippines combined with simulation); 📋 💻
	Claims and entitlements: price and income support programs, disaster assistance payouts	Price and income support; disaster assistance payouts (Smith and Glauber, 2012)		Farmers: less reliance on governmental support Government: more efficient spending than ex post assistance (Mahul and Stutley, 2010) ✦	Dependence on private insurance mechanisms

Types of evidence:

👀 Empirical observations (surveys, interviews, statistical analyses)
📋 Field / lab experiments
💻 Simulation studies / Analytical models
✦ Reviews and conjecture of others
↔ Contradictory results
No symbol: Own conjecture

Remark: Adverse effects occur mainly on a longer time scale. Columns 5 and 6 include studies that investigate impacts from change in column 4 as well, not only from insurance.

References:

Angelucci, M., De Giorgi, G. (2009) Indirect Effects of an Aid Program: How Do Cash Transfers Affect Ineligibles' Consumption? American Economic Review 99, 486-508.

Attanasio, O., Ríos-Rull, J.-V.c. (2000) Consumption smoothing in island economies: Can public insurance reduce welfare? European Economic Review 44, 1225-1258.

Babcock, B.A., Hennessy, D.A. (1996) Input Demand under Yield and Revenue Insurance. American Journal of Agricultural Economics 78, 416-427.

Baumgärtner, S., Quaas, M.F., (2009) Agro-biodiversity as natural insurance and the development of financial insurance markets, in: Kontoleon, A., Pascual, U., Smale, M. (Eds.), Agrobiodiversity, Conservation and Economic Development. Routledge, London, UK, pp. 293-317.

Berzsenyi, Z., Győrffy, B., Lap, D. (2000) Effect of crop rotation and fertilisation on maize and wheat yields and yield stability in a long-term experiment. European Journal of Agronomy 13, 225-244.

Bhattacharya, H., Osgood, D. (2014) Weather Index Insurance and Common Property Resources. Agricultural and Resource Economics Review 43, 438-450.

Boucher, S.R., Delpierre, M., (2014) The impact of index-based insurance on informal risk-sharing arrangements, in CEPS/INSTEAD Working Paper (Luxembourg), https://arefiles.ucdavis.edu/uploads/filer_public/26/64/2664c503-96b6-425c-a660-b02bb98a9e1b/boucher_delpierre_dec_2014.pdf, last accessed: November 3 2016.

Cai, H., Chen, Y., Fang, H., Zhou, L.-A. (2015) The Effect of Microinsurance on Economic Activities: Evidence from a Randomized Field Experiment. Review of Economics and Statistics 97, 287-300.

Cai, J., (2015) The Impact of Insurance Provision on Household Production and Financial Decisions. http://econweb.umd.edu/~davis/eventpapers/CaiImpact.pdf. Last accessed: November 3 2016. University of Michigan. October 14, 2014.
Capitanio, F., Adinolfi, F., Santeramo, F.G. (2015) Environmental implications of crop insurance subsidies in Southern Italy. International Journal of Environmental Studies 72, 179-190.
Carter, M.R., Galarza, F., Boucher, S. (2007) Underwriting area-based yield insurance to crowd-in credit supply and demand. Savings and Development 31, 335-362.
Chantarat, S., Mude, A.G., Barrett, C.B., Carter, M.R. (2013) Designing Index-Based Livestock Insurance for Managing Asset Risk in Northern Kenya. Journal of Risk and Insurance 80, 205-237.
Cole, S., Giné, X., Vickery, J., (2014) How Does Risk Management Influence Production Decisions? Evidence from a Field Experiment, Harvard Business School Working Paper, 13-080, September 9, 2014.
Corbeels, M., Marchão, R.L., Neto, M.S., Ferreira, E.G., Madari, B.E., Scopel, E., Brito, O.R. (2016) Evidence of limited carbon sequestration in soils under no-tillage systems in the Cerrado of Brazil. Scientific Reports 6, 21450.
de Nicola, F., (2012) The impact of weather insurance on consumption, investment, and welfare. (October 1, 2012). Available at SSRN: http://dx.doi.org/10.2139/ssrn.2169614. Last accessed: November 3 2016.
de Nicola, F., (2015) Handling the Weather: Insurance, Savings, and Credit in West Africa, in: Bank, W. (Ed.), Policy Research Working Paper 7187. Word Bank.
Dercon, S., Christiaensen, L. (2011) Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. Journal of Development Economics 96, 159-173.
Dercon, S., Hill, R.V., Clarke, D., Outes-Leon, I., Taffesse, A.S. (2014) Offering rainfall insurance to informal insurance groups: Evidence from a field experiment in Ethiopia. Journal of Development Economics 106, 132-143.
Dercon, S., Krishnan, P. (2003) Risk Sharing and Public Transfers. Economic Journal 113(486): C86-C94.
Ding, Y., Schoengold, K., Tadesse, T. (2009) The Impact of Weather Extremes on Agricultural Production Methods: Does Drought Increase Adoption of Conservation Tillage Practices? Journal of Agricultural and Resource Economics 34, 395-411.
Elabed, G., Carter, M.R., (2015) Ex-ante Impacts of Agricultural Insurance: Evidence from a Field Experiment in Mali. http://www.gdn.int/fullpaper/Paper%20for%20Session%2017-Elabed-Carter-Cotton-Ex-Ante%20Impacts%20of%20Agricultural.....pdf, last accessed: November 3 2016.
Faber, S., Rundquist, S., Male, T., (2012) Plowed Under: How Crop Subsidies Contribute to Massive Habitat Losses (http://static.ewg.org/pdf/plowed_under.pdf, last accessed: November 3 2016).
Fernandez-Gimenez, M.E., Le Febre, S. (2006) Mobility in pastoral systems: Dynamic flux or downward trend? International Journal of Sustainable Development and World Ecology 13, 341-362.
Finger, R., Möhring, N., Dalhaus, T., Enjolras, G. (2016) The effects of crop insurance on pesticide use. Paper prepared for the 156th EAAE Seminar, Prospects for agricultural insurance in Europe, October 3-4, 2016. Wageningen, The Netherlands.
Fratkin, E., Roth, E.A. (2005) As Pastoralists Settle: Social, Health, and Economic Consequences of the Pastoral Sedentarization in Marsabit District, Kenya (Studies in Human Ecology and Adaptation). Springer.
Fuchs, A., Wolff, H. (2011) Concept and Unintended Consequences of Weather Index Insurance: The Case of Mexico. American Journal of Agricultural Economics 93, 505-511.
Goodwin, B.K., Smith (2003) An Ex-Post Evaluation of the Conservation Reserve, Federal Crop Insurance, and other Government Programs: Program Participation and Soil Erosion. Journal of Agricultural and Resource Economics 28, 201-216.
Goodwin, B.K., Vandeveer, M.L., Deal, J.L. (2004) An Empirical Analysis of Acreage Effects of Participation in the Federal Crop Insurance Program. American Journal of Agricultural Economics 86, 1058-1077.
Henry, M., Béguin, M., Requier, F., Rollin, O., Odoux, J.-F., Aupinel, P., Aptel, J., Tchamitchian, S., Decourtye, A. (2012) A Common Pesticide Decreases Foraging Success and Survival in Honey Bees. Science 336, 348-350.
Hill, R., Viceisza, A. (2012) A field experiment on the impact of weather shocks and insurance on risky investment. Experimental Economics 15, 341-371.
Hodgkin, T., Rana, R., Tuxill, J., Balma, D., Subedi, A., Mar, I., Karamura, D., Valdivia, R., Colledo, L., Latournerie, L., Sadiki, M., Sawadogo, M., Brown, A., Jarvi, D., (2007) Seed systems and crop genetic diversity in agroecosystems, in: Jarvis, D., C, P., HD, C. (Eds.), Managing Biodiversity in Agricultural Ecosystems. Columbia Univ. Press, New York, pp. 77-119.
Janzen, S.A., Carter, M.R. (2013) After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection. National Bureau of Economic Research Working Paper Series No. 19702.
Karlan, D., Osei, R., Osei-Akoto, I., Udry, C. (2014) Agricultural Decisions after Relaxing Credit and Risk Constraints. The Quarterly Journal of Economics 129, 597-652.
Kassie, B., Hengsdijk, H., Rötter, R., Kahiluoto, H., Asseng, S., Ittersum, M. (2013) Adapting to Climate Variability and Change: Experiences from Cereal-Based Farming in the Central Rift and Kobo Valleys, Ethiopia. Environmental Management 52, 1115-1131.
LaFrance, J.T., Shimshack, J.P., Wu, S., (2002) The Environmental Impacts of Subsidized Crop Insurance: Crop Insurance & the Extensive Margin. http://econweb.ucsd.edu/~carsonvs/papers/830.pdf, last accessed: November 3 2016.
Landmann, A., Vollan, B., Frölich, M., (2012) Insurance versus Savings for the Poor: Why One Should Offer Either Both or None. Forschungsinstitut zur Zukunft der Arbeit (IZA).
Lin, B.B. (2011) Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. BioScience 61, 183-193.
Lin, W., Liu, Y., Meng, J. (2014) The crowding-out effect of formal insurance on informal risk sharing: An experimental study. Games and Economic Behavior 86, 184-211.
Lipper, L., Cavatassi, R., Hopkins, J., (2009) The Role of Crop Genetic Diversity in Coping with Agricultural Production Shocks: Insights from Eastern Ethiopia, in: Kontoleon, A., Pascual, W., Smale, M. (Eds.), Agrobiodiversity, Conservation and Econonomic Development. Routledge, New York, pp. 183-203.
Lithourgidis, A., Dordas, C., Damalas, C., Vlachostergios, D. (2011) Annual intercrops: an alternative pathway for sustainable agriculture. Australian Journal of Crop Science 5, 396.
Little, P.D., McPeak, J., Barrett, C.B., Kristjanson, P. (2008) Challenging Orthodoxies: Understanding Poverty in Pastoral Areas of East Africa. Development and Change 39, 587-611.
Lubowski, R., Bucholtz, S., Claassen, R., Roberts, M., Cooper, J., Gueorguieva, A., Johansson, R., (2006) Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy. Economic Research Report 25. U.S. Department of Agriculture, Economic Research Service.
Mahul , O., Stutley, C., (2010) Government Support to Agricultural Insurance: Challenges and Options for Developing Countries. Washington DC: World Bank.
Male, T., (2014) Mutually Insured Destruction How Unchecked Crop Insurance Subsidies Harm the Environment (Defenders of Wildlife, http://www.defenders.org, last accessed: November 3 2016).
Mobarak, A.M., Rosenzweig, M.R., (2012) Selling formal insurance to the informally insured. Yale Economics Department, Working Paper 1007. http://www.econ.yale.edu/growth_pdf/cdp1007.pdf, last accessed: November 3 2016.

Mobarak, A.M., Rosenzweig, M.R. (2013) Informal Risk Sharing, Index Insurance, and Risk Taking in Developing Countries. American Economic Review 103, 375-380.
Müller, B., Linstädter, A., Frank, K., Bollig, M., Wissel, C. (2007) Learning from local ecological knowledge: modeling the pastoral-nomadic range management of the Himba, Namibia. Ecological Applications 17, 1857-1875.
Müller, B., Quaas, M.F., Frank, K., Baumgärtner, S. (2011) Pitfalls and Potential of Institutional Change: Rain-Index Insurance and the Sustainability of Rangeland Management. Ecological Economics 70, 2137-2144.
Normile, D. (2013) Vietnam Turns Back a 'Tsunami of Pesticides'. Science 341, 737-738.
Norton, M., van Sprundel, G.-J., Turvey, C.G., Meuwissen, M.P.M. (2016) Applying weather index insurance to agricultural pest and disease risks. International Journal of Pest Management, 1-10.
Peterson, N.D. (2012) Developing Climate Adaptation: The Intersection of Climate Research and Development Programmes in Index Insurance. Development and Change 43, 557-584.
Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., Blair, R. (1995) Environmental and Economic Costs of Soil Erosion and Conservation Benefits. Science 267, 1117-1123.
Quinn, S., Dercon, S., Matul, M., (2014) Why and how does impact happen?, in: Radermacher, R., Roth, K. (Eds.), A Practical Guide to Impact Assessments in Microinsurance. Microinsurance Network and Micro Insurance Academy. http://www.microinsurancenetwork.org/groups/practical-guide-impact-assessments-microinsurance. Last accessed November 3 2016, pp. 41-60.
Santos, P., Barrett, C.B. (2011) Persistent poverty and informal credit. Journal of Development Economics 96, 337-347.
Schoengold, K., Ding, Y., Headlee, R. (2015) The Impact of AD HOC Disaster and Crop Insurance Programs on the Use of Risk-Reducing Conservation Tillage Practices. American Journal of Agricultural Economics 97, 897-919.
Sibiko, K.W., Qaim, M., (2017) Weather index insurance, agricultural input use, and crop productivity in Kenya, GlobalFood Discussion Papers 94, http://hdl.handle.net/10419/156699. Last accessed: April 29 2017.
Smith, V.H., Glauber, J.W. (2012) Agricultural Insurance in Developed Countries: Where Have We Been and Where Are We Going? Applied Economic Perspectives and Policy 34, 363-390.
Smith, V.H., Goodwin, B.K. (1996) Crop Insurance, Moral Hazard, and Agricultural Chemical Use. American Journal of Agricultural Economics 78, 428-438.
Stuart, D., Schewe, R.L., McDermott, M. (2014) Reducing nitrogen fertilizer application as a climate change mitigation strategy: Understanding farmer decision-making and potential barriers to change in the US. Land Use Policy 36, 210-218.
Tengö, M., Belfrage, K. (2004) Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania. Ecology and Society 9, 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art4/
Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S. (2002) Agricultural sustainability and intensive production practices. Nature 418, 671-677.
Toth, R., Barrett, C., Bernstein, R., Clark, P., Gomes, C., Mohamed, S., Mude, A., Taddesse, B., (2014) Productive Spillovers of the Take-up of Index-Based Livestock Insurance. Working Paper. August 2014. http://ageconsearch.umn.edu/bitstream/172441/2/2014%20June%2011%20ProductiveSpilloversIBLI.pdf, last accessed: November 3.
Vickery, J.A., Bradbury, R.B., Henderson, I.G., Eaton, M.A., Grice, P.V. (2004) The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. Biological Conservation 119, 19-39.
Waha, K., Müller, C., Bondeau, A., Dietrich, J.P., Kurukulasuriya, P., Heinke, J., Lotze-Campen, H. (2013) Adaptation to climate change through the choice of cropping system and sowing date in sub-Saharan Africa. Global Environmental Change 23, 130-143.
Wu, J.J. (1999) Crop Insurance, Acreage Decisions, and Nonpoint-Source Pollution. American Journal of Agricultural Economics 81, 305-320.
Zimmerer, K.S. (2010) Biological Diversity in Agriculture and Global Change. Annual Review of Environment and Resources 35, 137-166.