Environmental Change and Maize Innovation in Kenya: Exploring Pathways In and Out of Maize

Sally Brooks, John Thompson, Hannington Odame, Betty Kibaara, Serah Nderitu, Francis Karin and Erik Millstone

Maize

STEPS centre

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About the STEPS Centre

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Summary

This paper summarises findings from the STEPS Environmental Change and Maize Innovation in Kenya project. Maize is an important staple crop in Kenya, socially, politically and economically. This project has taken maize as a window through which to explore differential responses to the combined and inter-related effects of climate change, market uncertainties and land use changes over time. It has traced innovations and responses of various actors – public agricultural research institutions, governments, donors, development agencies, private companies and farmers. At issue is the way in which actors in different institutional, geographic and social locations understand and frame resilience - and how these framing assumptions shape agendas and steer solutions and resources in certain directions and not others.

The question 'why maize' has been a recurring theme throughout the research. Our findings highlight diverse and differentiated ways in which maize finds its way into multiple farming and livelihood systems – leading us to question a technology supply 'pipeline' model informing interventions to generate drought tolerant maize varieties and make these available – together with crop advice – through networks of private providers. These strategies share certain core assumptions: firstly, that an extension of the 'choice' of varieties available to farmers of their primary crop, maize, will respond to the diversity of local contexts in which farmers attempt to build sustainable livelihoods; and secondly, that this extension of choice is to be facilitated through an extension of the formal 'maize system', displacing a diversity of informal systems on which many resource-poor farmers rely. Designed in and for high potential maize growing zones, such technical-institutional arrangements are unlikely to 'trickle down' to and meet the needs of resource poor farmers in drought-prone areas of Eastern Kenya.

Faced with balancing multiple types of incertitude in their daily lives; farmers in dryland areas choose elements of formal and informal systems in ways that enable them to tap into multiple sources of socio-technical diversity, as a basis for building resilient, robust livelihoods. It is this precarious balance that may be undermined by linear approaches that seek to stabilise one system at the expense of multiple others. This paper argues that interventions that recognise the fragility of maize-dependent livelihoods, and attempt to promote alternative pathways in and out of maize, may hold more promise. However, such approaches face challenges in the context of cross-scale dynamics that keep farmers in even the most drought-prone areas 'locked in' to maize, discouraging local innovations that might have led to more sustainable livelihood options.

1. INTRODUCTION: WHY MAIZE?

Climate change and variability present new development challenges, particularly in Sub-Saharan African countries where the majority of the population depend on climate-sensitive activities such as agricultural production (Yamin et al., 2005, ACCESA, 2007, IPCC, 2007). In Kenya for example, where 80% of the population depend directly or indirectly on agriculture, major climatic events in recent years have included the droughts of 1991-2, 1992-3, 1995-6, 1998-2000 and 2004, the El-Niño rains that resulted in the floods of 1997-8 (Orindi and Ochieng, 2005) and the more recent droughts of 2008-9. These environmental changes create new burdens for those already poor and vulnerable (Yamin et al., 2005). For the most vulnerable groups, exposures to new environmental risks are 'the latest in a series of pressures and stresses' (Kasperson and Kasperson, 2001), with crop failures, food and income insecurity, malnutrition and ill health experienced as interconnected and mutually reinforcing.

The STEPS Environmental Change and Maize Innovation Pathways in Kenya project (hereafter referred to as the STEPS maize project)[1] has taken maize in Kenya as a window through which to explore different responses to environmental change. As the primary staple crop and a fundamental part of people's livelihood systems, maize is culturally and politically important and already the focus of major research and development efforts (McCann, 2005). Developments in maize provided a starting point from which to trace different types of *innovation* proposed by various actors - public agricultural research institutions, donors and private companies; and practiced within communities and broader social networks, in response to environmental change. At issue are the varying ways in which people in different institutional and geographic locations understand and frame *resilience*, for example as a property of seeds, farming systems or broader livelihoods; and how these framing assumptions shape agendas and steer solutions, programme designs and resources in certain directions and not others.

Given the ubiquity of maize in multiple, diverse livelihood systems across Kenya and elsewhere in Sub-Saharan Africa, national and international crop science institutions have responded with research into improved maize varieties more able to withstand the effects of drought and climate change. The goal of maize breeding for drought-prone conditions has been pursued by plant breeders in Kenya since scientists at KARI's dryland research station developed their first 'drought-escaping' *Katumani* variety in 1968[2], and at CIMMYT since 1975 (Heisey and Edmeades, 1999:18-19). In recent years these efforts have been given new

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[1] Project partners include the African Centre for Technology Studies (ACTS), Tegemeo Institute – Egerton University and the Centre for African Bio-Entrepreneurship (CABE), all based in Nairobi, Kenya.

[2] Interview, KARI, February 2009.

prominence in light of increasing concerns about the effects of climate change, and in 2005, 2007 and 2008, the Bill and Melinda Gates Foundation (BMGF) granted \$5.5m and \$33.3m to CIMMYT[3] and \$42.45m to AATF[4] to develop and disseminate drought tolerant maize varieties[5] in Sub-Saharan Africa.[6] Meanwhile, private seed companies, frustrated in their attempts to penetrate the more commercially attractive high altitude market dominated by a parastatal, the Kenya Seed Company, are pursuing a loss-lead strategy in drought-prone Eastern Kenya.[7]

These strategies contain certain core assumptions: firstly, that an extension of the choice of varieties available to farmers of their primary crop, maize, will respond to the diversity of local contexts in which farmers attempt to build sustainable livelihoods; and secondly, that this extension of choice is to be facilitated through an extension of the formal 'maize system', at the expense of the informal systems on which many resource-poor farmers currently rely. In particular, today's Green Revolution for Africa relies on the promise of a strengthened network of private agro-dealers to serve as a de facto extension service, disseminating commercially available technologies and crop advice.[8] This research, however, has highlighted diverse and differentiated ways in which maize finds its way into multiple farming and livelihood systems, which lead us to question the technology supply 'pipeline' model that ends in an interface between the agro-dealer and farmers as consumers of technologies. In this context, this paper argues, concerns about climate change present an *opportunity* to explore alternative 'pathways in and out of maize' (such as those promoted under the Government of Kenya's ARLMPII programme,[9] for example).[10] Attempts to find alternatives to 'lock in' to maize face considerable challenges however, which are explored in this paper.

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[3] http://dtma.cimmyt.org/ (10th April 2009).

[4] http://www.aatf-africa.org/aatf_projects.php?sublevelone=30&subcat=5 (10th April 2009); http://www.monsanto.com/pdf/sustainability/advertisement.pdf (10th April 2009).

[5] Or in the case of the AATF-led programme 'water-efficient' maize.

[6] http://www.gatesfoundation.org/grants/Pages/search.aspx (10th April 2009).

[7] Interviews, Pannar and Monsanto companies, Nairobi, November 2009.

[8] http://www.agra-alliance.org/ (9th September 2009).

[9] Arid Lands Resource Management Project II, under the Ministry of State for the Development of Northern Kenya and other Arid Lands (http://www.aridland.go.ke/index.php: 9th September 2009).

[10] http://www.iisd.org/pdf/2007/climate_early_maggie_opondo.pdf; http://web.worldbank.org/external/projects/main?pagePK=104231&piPK=73230&theSitePK=40941&menuPK=228424&Projectid=P078058.

1.1. Maize as a window

This following passage hints at the paradoxical nature of the relationship between the maize crop and Africa's agrarian landscapes. This 'New World crop', while in many ways ill-suited to the complex, diverse, risk-prone environments that characterise agro-ecosystems across much of the continent, has nevertheless proved to be a versatile and enduring 'repertory actor'. Alternately vegetable and grain, varieties of maize have been adapted over centuries to different agro-ecological and political-economic environments, steadily replacing traditional crops, such as sorghum, millet and cassava (McCann 2005). These transitions and contradictions have brought with them new uncertainties and vulnerabilities, now intensified in an era of economic liberalisation and shifting, unpredictable climate patterns:

> Africa's agrarian landscapes include two divergent responses to agrarian modernism, both of which reflect the impact of maize in the late twentieth century: one is a commercial maize landscape of uniform fields with an almost industrial order of crop rows, roads to markets, and the trappings of economic rationality. The other, by stark contrast, is a landscape of subsistence in which farmers cultivate small plots, distant from viable markets and dominated by maize. These economic and human landscapes of subsistence present to the eye Africa's classic historical, irregular patchwork plots, but on closer examination now include high proportions of maize as a grain and a primary household food supply. Though they offer quick meals to fill the stomach, fields of maize are increasingly dependent on the vagaries of rainfall and local markets (McCann, 2001:267).

The interpretation of agriculture in Africa in terms of 'two divergent responses' is a familiar one (cf. Thompson et al., 2007). The STEPS maize project has explored the second of these; characterised here in terms of 'landscapes of subsistence', through studies focused on field sites in contrasting agro-ecological zones to address the following questions:

• What are the upstream drivers shaping the direction of innovation pathways[11] around maize in Kenya, in response to environmental change? Which actors, institutions, frames and interests have become prominent in steering research and funding towards these chosen directions? How has this configuration evolved over time, and how is it likely to evolve in the future?

[11] The particular directions in which interacting social, technological and environmental systems co-evolve over time' (Leach et al., 2007).

• Which dimensions of resilience are emphasised and prioritised within mainstream debates and programmes and which are omitted or sidelined? What implications does this have for those most vulnerable to the impacts of environmental change?

• How are small-scale farmers and vulnerable groups responding to environmental changes, for example through on-farm selection, crop management practices and/or livelihood diversification? How do they conceptualise relationships between environmental change, its current/likely impacts on livelihoods, health and wellbeing and notions of resilience and vulnerability?

• How do these local innovations and coping mechanisms interact (or not) with formal R&D programmes and mainstream debates, and to what effect? What might agricultural research look like if it was designed help meet needs of poor farmers or vulnerable groups?

Community-level studies were conducted in two sites, selected to represent low (semi-arid), and high potential maize growing zones, Sakai Sub-Location, Kisau Division, Makueni (now Mbooni) District in Eastern Province and Soy Sub-Location, Likuyani Division, Kakamega District in Western Province. In each location, rapid rural appraisal exercises were followed by in-depth interviews with selected farmers from different wealth categories within each site.

These field studies were placed within a broader context of maize agriculture in Kenya by drawing lessons from time series panel data collected over a ten-year period (1997-2007) by the Tegemeo Institute, Egerton University for Makueni, Likuyani and Nakuru districts as representative of low, medium and high-potential agricultural maize growing areas (see figure 1). A report of this data analysis is included as an Appendix to this paper. The following data selected from the report (tables 1-3) is illustrative. Tables 1 and 2 highlight the importance of maize cultivation for all income groups and across all three study sites, while table 3 highlights the contrast between the three sites, and particularly between the 'low potential' site and the others, in terms of maize productivity.

Table 1: Mean percent contribution of maize to total crop value by income quintile (across all three sites)

Quintile	1997	2000	2004	2007	Quintile Mean
Lowest	46.6	31.3	43.1	38.6	**39.9**
2	43.4	34.6	38.3	37.1	**38.4**
3	33.7	27.7	36.1	31.8	**32.3**
4	35.0	28.8	40.7	32.1	**34.1**
Highest	34.1	23.9	38.4	32.3	**32.2**

Table 2: Proportion of area under maize in relation to total cultivated area

District	1997	2000	2004	2007
Makueni	57.2	52.8	55.8	63.2
Kakamega	48.0	46.3	48.9	51.7
Nakuru	62.9	65.2	63.8	64.5

Table 3: Maize productivity (kg/acre) by study district

District	1997	2000	2004	2007	Average
Makueni	297	379	298	506	370
Kakamega	514	740	1,014	1,179	862
Nakuru	936	388	1,305	798	857

This paper focuses specifically on findings from Sakai, selected as a study site for its location in a semi-arid, 'low potential' maize area, and for project partner ACTS' links with actors in the area though their involvement in an 'Increasing Community Resilience to Drought Project'[12], conducted in collaboration with the governmental Arid Lands Resource Management Project' (ALRMPII), under the Ministry of State for the Development of Northern Lands and Other Arid Lands in the Office of the President (which covers 28 arid and semi-arid districts, including Mbooni/Makueni).

An initial rapid rural appraisal (in May 2008) indicated that diversification – of maize varieties, crops and (on and off farm) livelihood options – appeared to be the main overall strategy for dealing with the challenges of increased rainfall variability and drought. On the return of the project team in December 2008, people were facing a second year of drought. This was during the 'short rains', the most important agricultural season in this area. That year, the rains had arrived late and had lasted only four days. Most farmers we met did not expect a maize harvest, nor had they harvested anything the previous year – so that their last harvest has been as far back as February 2007.

[12] This project is funded by United Nations Environment Programme (UNEP) and Global Environment Facility (GEF) and co-managed by ACTS, IISD (International Institute for Sustainable Development) and CSTI (Centre for Science, Technology and Innovation).

Figure 1: Map of Kenya showing research sites[13]

13 Source: CIA World Fact Book, 2004/Kenya.

2. DIVERSE PATHWAYS, MULTIPLE SYSTEMS: LESSONS FROM SAKAI

This section explores strategies employed by farmers in Sakai in response to the challenges of interacting environmental, market and land use changes, through the lens of maize in diverse farming and livelihood systems. In this section, we draw on group exercises and interviews with farmers in a semi-arid, 'low potential' maize growing area who, against the odds, continue to plant maize. This section highlights some of the ways in which complex cross-scale dynamics are experienced in the daily lives of farmers in different socio-economic groups, shaping the range of livelihood pathways available to them. In this case, rather than attempt to map a single maize system, maize is understood to play multiple roles in numerous and diverse systems. The accounts presented in this section point to 'multiple fault lines' (Kohnert, 2006:14) that map 'landscapes of subsistence' - calling for differentiated analysis at three levels: inter-sectoral (formal and informal systems), intra-sectoral (social stratification within the informal sector) and transnational (between local and global transnational spaces).

In considering future options for policymakers in Ethiopia, Gebreselassie et al (2006) identified four core pathways in agriculture: intensification, livelihood diversification, commercialisation and land consolidation, primarily through the exit (by small scale farmers) from agriculture (see figure 2).

Figure 2: Four core pathways to Sustainability[14]

	Low growth	**High growth**
High resilience	**Diversification** Varietal, crop and income/on-off farm diversification	**Exit** Migration, urbanisation, resettlement
Low resilience	**Intensification** Access to inputs, Green Revolution	**Commercialisation** Small farms, large farms, land reform

In this section, selected cases of Sakai farmers from different socio-economic groups are presented, illustrating how the livelihood options pursued by different farmers re-combine elements of (varietal, crop and income) diversification, intensification, commercialisation and perhaps even initial steps towards exit from agriculture (although findings presented in a later section highlight the choice of some to use off-farm income to invest in re-entering farming on very different

[14] Adapted from Thompson (2008).

terms – see box 6). In the process, farmers draw on both formal and informal seed systems, at different times and in different ways, confounding the stereotype of informal systems as purely a 'fall back' when formal systems 'fail'.

2.1 Maize in Sakai: A brief history

Prior to national independence, farmers in Sakai grew a range of dryland crops including sorghum and millet. Since the early 1906s however, farming practice has steadily shifted towards maize as the primary crop. The introduction of primary schooling played a major role both in eroding the cultivation of traditional crops, particularly sorghum for which children's role in bird-scaring formed an essential part of the farming system, and in creating a market for maize as the premier cash crop for the payment of school fees.[15]

Maize cultivation in Sakai since that time can be divided into three phases. Figure 3 shows a 'maize biography' for Sakai. From the early 1960s, farmers planted local varieties known as *Kikamba* or *Kinyanya*. In reality these were composites rather than pure varieties, due to cross-pollination with neighbouring plants or introduced grains (for example through the food aid initiatives). In the mid 1970s, scientists at the KARI research station at Katumani developed their flagship early maturing *Katumani* variety (and subsequent composites, including the more popular KCB) as a 'drought escaping' (early maturing) crop. A concerted effort was made by government extension officers at this time to introduce the new variety to local farms.

From 2000, following the liberalisation of the seed sector, a range of commercial varieties became available, though they had to be purchased from stockists more than ten kilometres away, and, for the first time, farmers became 'consumers' of seeds. During the same period there were also a series of donor interventions that brought maize seed and/or grain. In 2002, other varieties were introduced as relief seed by World Food Program (WFP). In 2006, concerned about the risks some farmers were taking in experimenting with the high yielding (but drought sensitive) hybrids, the Government of Kenya ALRMPII project attempted to stimulate flagging interest in the 'drought escaping' KCB and DLC1.

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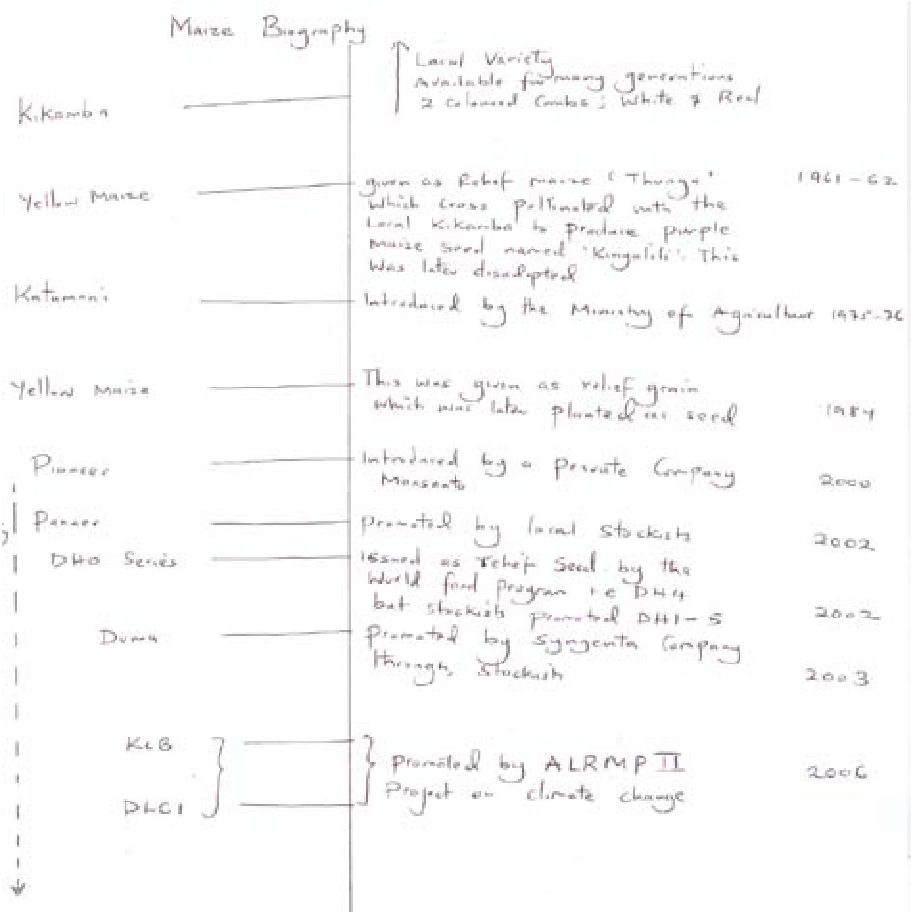
[15] Interviews, Sakai farmers, December 2008.

Figure 3: Maize biography[16]



From the 2000s onwards, therefore, more varieties had become available in the local seed and input stockists. However, in spite of the availability of these commercial varieties farmers in Sakai continue to plant traditional, local varieties. Box 1 shows the criteria used by a group of women, drawn from the villages in Sakai, which they use to decide which varieties to plant. Notably, availability and price are top of the list. Characteristics related to yield – often assumed as the most important trait – were assessed as lower priority. Furthermore, given their responsibilities for making porridge for children, for example, the specific

[16] Source: Rapid rural appraisal, Sakai, May 2008.

quality of 'giving good flour' was highlighted (rather than the more generic 'yield' trait). Interestingly, despite the increase in choice, the local *kikamba* rated highest overall and particularly in the most important categories.

Box 1: Criteria used by a group of women in Sakai to assess maize varieties

Availability (*kukwatikana kwa mbeu*) of the seed was ranked as the most important criteria to the women as this is an assurance that their families will always have food regardless of the season. *Kikamba* (local) variety is readily available amongst the farmers and it was clear that at least this seed is available in every homestead.

Price of the seed (*thoowa was mbeu*) was also important and ranked second; the kikamba was ranked the cheapest as the farmers exchange the seed amongst themselves.

Early maturing (*ilasianaa mituki*) was ranked third. With an early maturing variety of seed, the farmers are assured of a harvest, however small, even if the rains disappear after a few days. The early maturing varieties most commonly planted and *Katumani* Composite B (KCB), which matures within two and a half months; and the local *kikamba* variety which matures within three and a half months.

Fullness of the cob (*usuu was kisakwa*) is also important as this translates to a higher yield. The *Duma* variety is highly responsive to manure and when the rains are reliable, the variety gives relatively full cobs.

The weight of the seed (*uito wa mbeu*) was also among the most important traits as this means that the seed will produce a good amount of flour and will also fetch a good price at the market. The local *Kikamba* variety has a relatively heavy seed and is therefore good for flour production. Although the seed is not as large as is the case for the *Duma* variety, nevertheless it gives good flour.

Response to manure (*kwailya kwa vuu*) was ranked as the least important, since most farmers in this area rarely use manure and fertilizer. Fertilizer is very expensive and most of the farmers in this village do not keep livestock so manure is not readily available.

Source: Rapid rural appraisal, Sakai, May 2009

Clearly kikamba seeds are not bought from the local agro-dealer. Farmers source these locally, from seed saved from the previous years' harvest, or sometimes from respected people in the community known for their skill in selecting good seed. *Kikamba* seeds, in fact, form part of a local seed system which relies on knowledge and skills passed down through the generations (see box 2).

Box 2: On–farm seed selection in Sakai

The seed selection process begins at the field level. After identifying a good maize cob in the field, the maize plant is marked, for example, by cutting two leaves before drying. The mark is placed on plants that produce a cob at the 4th or 5th 'node'. At harvest time, the seed selector goes to the marked plants which are harvested first. The preferred characteristics for seed selection include high yields and short time to maturity. Early maturing crops in particular give better seeds, stem size, size and weight of cob and colour of seed. Upon drying, further selection is based on:

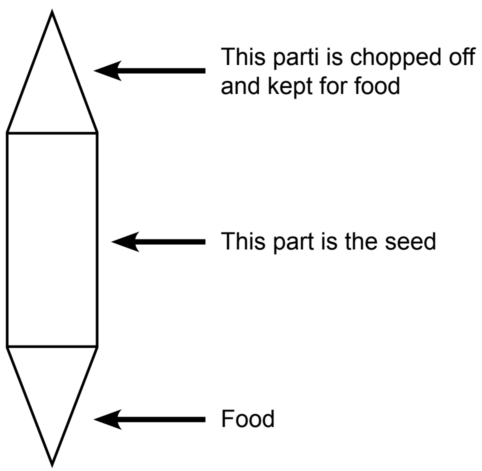
- Size of cob/length of cob – Long cobs produce good seed

- Fullness of a cob – A full cob gives better seed

- Size of grain – The grains should be large and well shaped

- Hardness of grain.

Once a cob has been selected, the ends are chopped off and the midsection is kept as seed, see below:



There are two methods of seed storage: the traditional method includes storing seed in Kisua by hanging the maize cobs in pairs over a fire place. The maize cob stays on the Kisua for one year; during this time, the maize is hardened by the heat from the fire and also covered by a layer of soot, thus increasing its resistance to pest infestation. This method continues to be used in preference to the second, modern method of post-harvest chemical storage.

The traditional method is preferred because it is inexpensive. Also the recent incidence of fake pesticides discourages farmers from buying chemicals. For some seed selectors, a few days before planting, 10kg of seed is mixed with 1kg of soot in an adequate amount of water. The mixture is left to dry for 3-6 days. These seeds cannot be destroyed by insects such as termites which mean it can be planted way before the rains. Also, there are no side effects as is the case with pesticides.

The issue of trust is very important for seed selectors. For Sarah, her seeds are very reliable because whatever she plants 'never fails to harvest'. She plants early enough, uses everything needed to ensure the plant does well (including the recommended amount of manure) and harvests early. She makes sure she has enough popular seeds in stock. As she says: 'The *Kamba* people always want seed that does well.' Sarah pointed out that farmers are more likely to trust the local seed selectors than the commercial seed stockists because they are assured availability of seed adapted to local conditions and at a price they can afford.

The seed selectors work closely with young members of their families (including children and daughters-in-law) in seed selection and storage. In so doing they are able to pass their knowledge to the younger people. Joseph works with two granddaughters who have been trained. His daughter-in-law, who is around the age of 40, is keen to learn the 'art' of seed selection. In the past in his household, seed selection was done by his parents and his wife. Today, his two children (both adults and married) have taken up the practice, as have his married daughter and two unmarried sons. Apart from working with family members, Joseph has trained at least two of his neighbours in seed selection. He says that in the past seed selection knowledge was transferred to us by our parents but today the knowledge is passed to others through farmer-to-farmer initiatives, through field days and also through parents.

Source: Interviews with five seed selectors, Sakai, May 2008.

These discussions indicate that there are at *least* two maize systems operating in Sakai, a formal system incorporating public and private sector institutions, and an informal one, within which local seed selectors play an important role. This section, however, has focused on maize in isolation. The next section explores the various roles maize plays in farming and livelihood systems.

2.2 Maize in a system

The previous section highlighted the importance of local institutions for maize seed selection. Boxes 3 and 4 tell us more about two of the seed selectors interviewed, showing that while they share certain types of knowledge and skill, their different socio-economic status is reflected in very different livelihood systems in which maize plays a markedly different role.

Box 3: Maize in a system – in a 'middle class'[17] household

Alice plants maize, beans, cowpeas, pigeon peas, sorghum, cassava and fruit trees. The maize varieties grown are DK 8031, Duma DHO2 and DHO4 (all hybrids) and the local *Kikamba* variety. The hybrid maize varieties are bought from the stockist in the nearest shopping centre of Mbumbuni or Wote and the local varieties are selected from her own harvest – in fact she is well known in the area of a supplier of good, reliable local seed. The Duma and *kikamba* varieties are both tall (with a long stalk). So she plants them next to the homestead as the chicken cannot reach the cob. The KCB variety, on the other hand is short, so she plants it further away from the homestead so the cobs are not eaten by the chickens. Alice also grows vegetables during the rainy season. She has a shallow well where she collects water for the vegetables. She has started growing mangoes, oranges and lemons which she hopes to start selling when they mature.

She uses farmyard or compost manure for planting and (commercially available) topdressing fertilizer. She doesn't mix fertilizer and manure. She collects farmyard manure from the cowshed as she has eight cows; three dairy cows and five calves. Fertilizer is purchased from *Mbumbuni* market and the compost manure is prepared in a pit near the homestead. During planting, she prefers to put the manure on the furrows, rather than broadcasting or placing directly in the holes (as this causes the seeds to rot).

Alice doesn't sell her maize harvest. All is kept for subsistence - it is just enough to feed her family until the next season, though she sometimes sells vegetables which she grows when there is enough rain; or purchases from *Mbumbuni* market and brings to *Muiu* market to sell. She rarely employs farm labour as her family is able to do all the farm work. She owns a nursery school which she started in 2006. Her husband owns a butchery and restaurant at the shopping centre. Annually, she makes about 4000KES from the nursery

[17] This farmer was assessed as 'rich' by key informants, Sakai, December 2007. However, she regards herself as 'middle class'.

school and about 2000 KESfrom the sale of vegetables. Sometimes she receives remittances from her sons of about 1000 KES annually.

Alice categorizes herself as middle class. 'The rich have big farms, their children have permanent jobs in big cities, have invested heavily and are able to educate their kids in good schools' she says. Those that are below her, the poor and the very poor may have no livestock, receive no remittances and probably have very young children. Comparing the past and the future - she feels that life was cheaper in the past as the economy was better. She also had a job as a nursery school teacher. She thinks that in the future, life will be harder as the economy is deteriorating by the day. She also thinks that if her children get better jobs, more permanent jobs, she will be more comfortable as they will help her.

Source: Interview with middle class farmer, Kathamba Village, Sakai, December 2008

The household described in box 3 illustrates well the different dimensions of 'maize in a system'. Firstly, maize, while clearly central to this farming and livelihood system, is integrated into a diversified intercropping system. Furthermore, while grown for family subsistence, a dependable maize harvest provides a foundation for a range of crops grown for subsistence and cash. In addition, there is considerable varietal diversification within maize itself. Alice's skills as a seed selector are important, both for ensuring a good harvest for family consumption and for consolidating her status in the community. The decisions she makes in selecting maize and other crop varieties, however, have to be placed in the context of a seasonal cycle of crop-livestock-nutrient interactions and how Alice manages its various elements. Unlike other farmers interviewed, her household has access to a water supply, as well as enough livestock to generate manure for the farm. And while the extent of its contribution to the running of the farm is not entirely clear, the role of steady, non-seasonal off-farm income is clearly an important factor in ensuring the family's 'middle class' (or 'rich') socio-economic status.

While Alice perceives a gradual fall in the family's standard of living, this seems more a reflection of her reading of the state of the national economy as a whole, whose effects may yet be countered by future remittances from children she has been able to support though school. Her story of hard work ultimately reaping its rewards stands in contrast to the next story, outlined in box 4, of a 'poor' household struggling to maintain a sustainable farm and livelihood system. Veronica, like Alice, practices intercropping and nutrient recycling and is skilled in seed selection. Crucially, however, she has no water supply so is unable to practice horticulture, a potential alternative to maize dependence in this area. Forced to rely on maize alone, she is unable to grow quite enough food for family subsistence. To make up this shortfall, both she and her husband have to rely on the vagaries of the local, seasonal labour market. Though skilled in seed selection, too often she is forced to use saved seed as grain for family consumption, with the result that she has to purchase (probably inferior) seed for planting the next season. Looking to the future, it seems unlikely that her children will remain in school long enough to gain the kind of employment that Alice's children will be able to secure and support the family.

Box 4: Maize in a system – in a 'poor'[18] household

Veronica's family plant maize, beans, cowpeas and pigeon peas on their farm. They also have a few mango, lemon, orange, avocado and banana trees. She has seen how well fruit trees are doing in her neighbour's farm despite the low rains in the area and she has now planted more fruit trees. She hopes that in the future these trees will produce enough for her to sell. This way, her family will be less dependent on maize, which has been producing poorly season after season. She intercrops the legumes and cereals. She doesn't grow vegetables on her land due to shortage of water and poor rains; these she buys from the nearest market called *kilala* at approximately ten shillings for a bunch of *sukumawiki*.

The varieties of maize planted on her farm are DHO4 and local *Kikamba* varieties. She planted Duma variety in 2007 but it did not perform very well. She has also tried to plant DHO2 variety in 2007 but the rains disappeared soon after planting and what remained was eaten by squirrels. In the previous years when the rains were more reliable, she would borrow land from a relative, who has quite a large piece of land where she would plant more maize. DHO2 is planted near the homestead as the bench terraces near the homestead are much bigger than those downstream. The local variety, *kikamba* is planted further away on the smaller bench terraces.

For the local *kikamba* variety she selects the seed to plant from her harvest. She learnt the art of seed selection from her mother-in-law who was also a farmer. She selects and marks the early maturing maize plant whose cob is full, the grain from the marked plants are kept aside as seed. From last season's harvest, she had kept aside five kilos as seed but the drought was too much in the month of August. 'I had to somehow provide food for my children when the drought hit really hard' she says, therefore they consumed the grain that had been kept aside as seed. When the planting season came, she had to purchase about four kilograms of *kikamba* from the neighbours at 35KES per kilo.

[18] Wealth ranking by key informants, Sakai, December 2007.

All her maize harvest is for subsistence use. For the last two years, the best harvest that her farm has ever produced was five bags of maize, two *debes* of beans (about 40 kg) and this was in the July-August 2007season. This harvest fed her family for about six months after which she had to start buying food from the market. Of late she has been harvesting approximately two or three bags of maize which lasts the family of eight a much shorter period. In 2006, the rains were very good. However, she was sick, and managed to harvest only two bags of maize while the cowpeas, pigeon peas and the beans were consumed while still green in the *shamba* (farm). They therefore didn't have anything to store.

She has never used inorganic fertilizer on her farm; 'I can't afford fertilizer, that is for the rich' she says. She only uses compost and farmyard manure. The farmyard manure is collected from the cow shed; she has two local breed cows that are used for ploughing. She has a compost pit next to her house where she collects leaves, ash and vegetable peelings etc. The compost is prepared for about three months before it is ready to be used in the farm. They normally use it during land preparation. The compost manure is applied on the farm one week before planting. It is distributed evenly in the furrows before planting. They sometimes mix it with farmyard manure in equal proportions. This however depends on which of the two will be more available. She doesn't do any top dressing on her crops as she cannot afford it.

Her husband works as a casual labourer in a neighbouring farm where he is employed full-time and is paid a monthly salary of 2,500 KES. She supplements this income by doing seasonal, casual jobs in the neighbouring farms e.g. ploughing, weeding, etc. She raises an average of 500 KES on a good month. Her money is normally for domestic use. Her two sons who are 13 and 14 years old accompany her for the casual jobs. Since her children are still in primary school, they are benefiting from the free primary school education scheme sponsored by the government. She is however worried as her first born has just completed standard eight and will be joining high school. She is worried about where his school fees will come from. She considers herself poor but not extremely poor as there are other people in her village who are worse off than she is. 'I can at least provide for my family, I don't have to depend on relief food' she says. There are those in her village who are very elderly and therefore cannot do any casual work to get money. The rich are those who own businesses or are employed and live in the larger cities.

Source: Interview with 'poor' farmer, Muiu Village, Sakai, December 2008

The cases outlined in boxes 3 and 4 both highlight multiple livelihood strategies, but they are, arguably, of a very different quality. What differentiates these two cases? While Alice appears to have responded to opportunities, the case of Veronica and her family appears to be a classic case of 'coping' with vulnerability by pursuing options – such as seasonal labour – that are themselves sources of further vulnerability and uncertainty. Is it, then, a question of whether people are 'pulled' by opportunity or 'pushed' by vulnerability? The following case of a 'very poor' household presents a yet more nuanced picture, in which a family walks a fine line between vulnerability and opportunity in trying to build a better future.

Box 5: Living on a knife-edge: between vulnerability and opportunity

Until two years ago Balthazar always planted the local *kinyanya* maize variety, using saved seed. However, in 2006, after a fall in yield from the usual 10 bags to only 7 bags, he decided to experiment with varieties he had seen doing well on his neighbours' farms. In the short rains season of 2006-7 he planted 6kg of *kinyanya* along with 2kg of KCB[19] and 1kg of Pioneer seed. The Pioneer seed had impressed him the most but it was expensive, at KES 400 for a 2kg packet. So he split the cost of one packet with a neighbour and they planted 1kg each. The KCB was far less expensive, at KES 10 per kg, since it came from a local seed bulking initiative supported by the Arid Lands project (ALRMPII).

The following year the rains failed. Balthazar harvested just one bag of maize, while none of his other crops produced any harvest. While he is accustomed to supplementing his family income through casual labour (at anywhere between KES 200 and KES 400 per day), in 2008 it became their main source of livelihood for a more extended period. At the same time, with crop failures widespread, demand for labour fell and competition for work intensified. It was a stressful time. As the year went on, he would sometimes be forced to sell a chicken or goat to buy food for the family. In late 2006, the family owned ten goats, now they have only four. However, with no unexpected expenses (such as medical bills) they managed to feed the family, though the parents often went without food to ensure there was enough for the children.

Balthazar is worried that if the maize crop fails again, next year he won't be able to afford certified seed, and *kinyanya* seeds won't even be available so 'planting will become a dream'. Meanwhile, he is experimenting with another enterprise. He points to fruit trees planted around the farm, which he sees as gradually replacing maize as the primary crop. At the end of his farm is a tree nursery and vegetable garden, both irrigated from a shallow well (which he dug himself). He runs the horticulture enterprise (tomatoes and kales) during

[19] Katumani Composite B.

the dry season when demand is high. Compared to his other income earning activities, the return on these activities has been good. With minimal input costs, fruit tree seedlings sell at KES 10 to KES 20 each. By selling 100-300 seedlings per year he can make as much as KES 6,000 in a year. This is in addition to profits from the horticulture enterprise of between KES 1,000 and KES 2,000.

Source: Interview with 'very poor'[20] farmer, Kathamba Village, Sakai, December 2008

As before, the case of Balthazar contrasts sharply with the following story of a farmer who has been able to invest his government salary back into the farm, building a highly diversified agricultural enterprise, in which maize is notably absent, which also serves as a model of 'farming as a business' that he hopes his children will follow.

Box 6: Farming as a second income? Re-entering agriculture on new terms

This household has a widely diversified crop mix, especially horticultural produce. These crops are more for cash than subsistence. Citrus fruits lead the pack bringing revenue in excess of KES 10,000 per annum. Kales (*Sukuma wiki*), tomatoes and onions are significant revenue contributors. In recent times they have been planting mangoes and pawpaw. In future the family stands to earn more income, especially from the expanding mangoes. Bananas are also being expanded and this will ensure food availability and some income from any surpluses. In addition, family also possess a tree nursery from where they sell trees to neighbours for planting thus generating further income for the household.

It is important to note that none of the household members sells labour to earn income, except Ezekiel who is employed as a primary school teacher. His wife and older children play an important role in providing labour on the farm. Each one of the grown up children is given a portion of the farm to plant crops that can be sold, mostly horticultural. Each one is given full responsibility to manage his portion and control the revenue with the guidance of the parents. For example, Ezekiel, their 19 year old son, manages *sukuma wiki,* sugar cane and a tree nursery. Revenue obtained from these activities has been used to purchase a bicycle for the boy and a water pump for the family.

Source: Interview with 'rich'[21] farmer, Kiteani Village, Sakai December 2008

[20] Wealth ranking by key informants, Sakai, December 2007.
[21] Wealth ranking by key informants, Sakai, December 2007.

These findings reveal that maize forms part of diverse farming and livelihood systems – in which decisions about which varieties to plant, and where, depend on particular configurations of family and farm. When scientists interviewed for this study were asked about maize in Sakai, however, they would invariably say 'well of course farmers there shouldn't grow maize'. Yet they continue to do so, despite the advisability of moving out of maize and into alternative crops (some of which were habitually grown and consumed just one or two generations ago) that would fare better in the prevailing harsh conditions. In Sakai, the shift from dryland crops to maize seems hard to reverse. People's tastes have changed, as have local knowledge and practices in food preparation.

Very few farmers in Sakai are able to follow the example of the farmer in box 6 and exit maize agriculture completely. To understand the reason for this requires analysis across scales, taking into account the interactions between decisions at family and community levels and the dynamics of the wider food system. At present, farmers have limited confidence that the national food system will deliver maize, at a price they can afford. These shortcomings were exposed in the previous year, exacerbated by shortages caused by the post-election violence of 2007-8, together with unstable fertilizer prices (which caused many farmers to plant without fertilizer, drastically reducing yields). It seems that the political economy of maize as it plays out on the national stage locks farmers in this locality into a crop they feel they must plant (at huge cost to themselves) 'just in case' the national food system fails to deliver – as it has in recent years. As one scientist remarked:

> If I had my way … the Rift Valley can produce all the maize this country needs. *Kambas* [people in Makueni] can produce all the pigeon pea and cowpea; Central Kenya can produce all the Irish potatoes; Western Kenya can produce all the sorghum and millet.
>
> But politics cannot allow all this to happen. That's why it's difficult to convince *Kambas* not to plant maize … what [would they have] to fall back on? It's insurance for them.[22]

However, attempts to promote alternative crops at local levels are undermined by national food system dynamics that neither assure access to affordable maize meal, nor provide reliable markets for crops which might otherwise have provided farmers in Sakai with viable alternatives to maize. In this context, farmers persevere in planting a crop which typically provides a harvest for two or three out of every ten years.[23] It is these cross-scale dynamics that lock farmers in areas like Sakai into maize cultivation.

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[22] Interview, KARI, February 2009.

[23] Interviews, ARLMPII, September 2007 and KARI, February 2009.

As mentioned in the introduction, a new generation of initiatives has been launched in recent years to address the problems facing farmers in drought prone areas like Sakai. Will these initiatives help to open up discussions about the potential of alternatives such as those presented here? Or will they reinforce pre-existing path dependencies that have led to ‘lock in’ to maize? These questions are explored in the next section.

3. FRAMING RESILIENCE – NARROWING DOWN THE OPTIONS?

The first part of this paper explored a range of farmers' responses and strategies in drought-prone regions of Kenya. In practice, however, some strategies are more visible than others, and more likely, therefore, to receive support and funding. This was the rationale for initiating the STEPS maize project – to better understand the processes through which the multiplicity of possible options comes to be narrowed down to a more limited set of policy prescriptions and interventions. This part of the paper explores these processes of 'narrowing down' options in the search for solutions to the problem of securing a sustainable future for African agriculture, in the context of climate change. In each case, this paper argues, proposed solutions are underpinned by an implicit framing of resilience – what it is, where it is located, and how it might be enhanced.

These solutions can be seen as being broadly composed of two, complementary strategies. Firstly, a plant genetics-led approach is proposed to build resilience into the seed by breeding or engineering drought tolerant varieties of maize. This framing taps into a set of assumptions on which the original Green Revolution, which took place in Asia and Latin America in the 1960s and 1970s, was based, that desired socio-technical changes could be embedded in the seed and therefore scale-neutral (for example, see Cullather, 2004). Secondly, a technology supply pipeline is envisaged (cf. Rogers, 2005), through which these (and other) commercial varieties will flow, extending the choice of seeds (and other inputs) available to farmers. With the decline in government extension services, this role passes to private providers as de facto extension officers and providers of agricultural inputs and advice to poor farmers, who now cast as 'consumers' of an expanded range of products (in this case, seeds).

The sections that follow draw on key informant interviews and document analysis to highlight the ways in which dominance of these overlapping visions frames out the complexity of choices facing farmers in different socio-economic conditions. In this way, dynamics of socio-ecological change and response are recast in a more stable and manageable form; amenable to the type of large-scale, 'silver bullet' solutions being proposed.

3.1 Investing in crop research: building resilience into the seed?

In 2006 two major programmes were launched to tackle the problem of resilience in African agriculture by developing maize varieties more able to withstand water-limited conditions. While these programmes feature different technologies and institutional configurations, both are funded by an influential new donor of initiatives aiming to reinvigorate African agriculture, the Bill and Melinda Gates Foundation (BMGF). This section briefly describes three phases in breeding for water-limited environments: firstly, the development of early maturing crops able to 'escape' drought; secondly, following the innovation of the 'managed stress environment', the development of varieties better able to better withstand a range of biotic and abiotic stresses including drought and variable rainfall; and thirdly, a concerted effort to establish a technology 'pipeline' to deliver drought tolerant maize varieties to farmers across Sub-Saharan Africa.

Drought-escaping varieties (1960s-70s)

'One of the first principles of crop improvement is to fit the variety to the growing season' (Heisey and Edmeades, 1999:18). For maize breeders at KARI's dryland research station at Katumani[24], therefore, their first response to water limited conditions was to develop early maturing varieties that were 'drought-escaping'. The first of these, an open pollinated variety (OPV) named *Katumani*, was released in 1968[25]. In the years that followed, KARI maize breeders released a series of composites developed from *Katumani*. Of these, *Katumani* Composite B (KCB), released in 1975, was the most successful and remains popular with farmers in the target area.[26]

Nevertheless, the 'drought-escaping' solution had its limitations, since early maturity comes at the expense of lower yield (Heisey and Edmeades, 1999:18). For farmers in an area like Sakai, where they can expect a harvest possibly only two or three years out of every ten years, investing their limited resources in inputs that may or may not yield a harvest is always a gamble. In such environments,

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[24] KARI Katumani's mandate is to develop varieties for 'areas of the country where the rainfall is not conducive to maize growing' - between 250-600mm per annum (Interview, KARI, February 2009).

[25] Interview, KARI, February 2009.

[26] Maize variety ranking and scoring exercise with farmers in Sakai, May, 2008. KCB has also been the focus of an 'informal assisted' seed bulking exercise with selected Sakai farmers under the UNEP/GEF-funded 'Increasing Community Resilience to Drought in Makueni District', in associated with the governmental ARLMPII project (see chapter 4 for a detailed discussion of this case, and of the challenges of attempting to bridge the informal and formal seed sectors in Kenya).

many farmers minimise risk by planting saved local seed rather than investing in commercially available varieties. When above average rainfall is forecasted, they will often elect to maximise returns on what is always a risky investment by planting higher yielding hybrid varieties.[27] These precarious dynamics of balancing investment, risk and uncertainty in farmers' decision making has tended to limit the adoption drought-escaping varieties.

From the 1980s onwards, breeders increasingly recognised the limitations of relying on the characteristic of time to maturity in breeding for drought conditions, and the need to find mechanisms for increasing drought resistance or tolerance that would not incur a yield penalty. In the 1990s, scientists in CIMMYT's Southern Africa breeding programme made a methodological breakthrough, leading to a new phase in maize breeding.

Breeding for stress tolerance (1980s-90s)

Breeding for drought has been a priority for CIMMYT breeders in Mexico from the 1980s onwards, and in the 1990s materials and new methodologies were introduced into CIMMYT's Africa programme. Until this time, formal plant breeding for all environments, favourable or unfavourable, began with selection in ideal conditions as produced in the research station. There were good reasons for this. Breeding in stress environments has always been problematic, since 'genetic variance and breeding progress are less than under high-yielding conditions... The exploitation of genetic progress has therefore often been connected to the use of inputs and breeders have focused on favourable and high-input conditions' (Bänziger and de Meyer, 2002:271)

In the late 1990s, researchers on CIMMYT's 'Southern African Drought and Low Soil Fertility Project' (SADLF) piloted a new breeding methodology for a range of 'managed stress conditions', including drought stress, in Zimbabwe (see McCann et al, 2006). This methodology was applied on a wider scale within a joint CIMMYT-IITA[28] initiative, launched in 1998 entitled: 'Developing and Disseminating Stress-Tolerant Maize for Food Security in East, West and Central Africa' - better known as the Africa Maize Stress (AMS) project (Bänziger and Diallo, 2000:1-2). This methodology combined selection in representative (rather than optimal) environments within a set of strategies that otherwise maintained the conventional tenets of formal plant breeding:

> Thus, the considerations that made this breeding approach for low input conditions successful seemed to have been: (1) choosing selection environments that individually represent the most important stress factors effective in the target environment over space and time; (2) apart from the selected stress factor, managing all other experimental and

[27] Interviews with farmers in Sakai, February 2009.

[28] International Institute for Tropical Agriculture.

> agronomical factors optimally; (3) making selection decisions based on results combined across managed stress environments and non-stress environments (Bänziger and Cooper, 2001:507).

This project was also innovative in other ways, adapting the 'mother-baby' model for participatory varietal selection into the breeding programme (de Groote and Siambi, 2005, Sawkins et al., 2006), which was part of a broader initiative, mobilising public and private actors throughout the maize value chain, through 'maize working groups' established in each participating country.[29] An evaluation of this 'flagship project', conducted in 2006, highlighted the AMS as a 'model project', which is now being extended to other countries.[30] Meanwhile it provided the platform for the development of a parallel breeding initiative, specifically targeting maize breeding for drought tolerance, financed by an injection of funds from a new donor, the Bill and Melinda Gates Foundation (BMGF).

Drought Tolerant Maize for Africa (DTMA)

Breeding for stress environments in Sub-Saharan Africa had so far been framed in terms of ongoing conditions of declining soil fertility and water scarcity. In the 2000s, two important shifts took place, firstly the formation of a new impetus towards, and an Alliance for a Green Revolution for Africa (AGRA)[31], supported by the BMGF; and, secondly, a reframing of the problem of 'drought' in Sub-Saharan Africa as a consequence of climate change which, while global in scope, is likely to disproportionately affect African farms and farmers. These two shifts combined have raised the profile of plant breeding for drought; and this is particularly the case for maize breeding, since 'compared to wheat and rice ... maize is more likely to be grown in areas that are regarded as marginal' (Heisey and Edmeades, 1999:2). This section reviews two major initiatives responding to these new imperatives, both funded by the BMGF, and both now focusing down on one crop and one source of stress - drought. The first of these is the CIMMYT-led Drought Tolerant Maize for Africa (DTMA) initiative (See box 7).

Box 7: Drought Tolerant Maize for Africa

'The **DTMA Initiative** joins the efforts of people, organisations and projects supporting the development and dissemination of drought tolerant maize in Sub-Saharan Africa (SSA). The work builds on CIMMYT's recognized efforts to develop and perfect the science of breeding for drought tolerance in maize. The **Drought Tolerant Maize for Africa Project** is part of the DTMA Initiative and is supported by the BMGF and Howard G. Buffet Foundation to accelerate drought tolerant maize development and deployment in 13 countries in SSA.

[29] Interview, CIMMYT, February 2009.

[30] http://www.cimmyt.org/english/wps/news/2006/mar/modelProject.htm (10th April 2009).

[31] http://www.agra-alliance.org/ (10th April 2009).

Drought tolerant maize varieties – a reality?
Maize is by nature a highly diverse crop and its tolerance to drought can be significantly enhanced through appropriate breeding techniques. CIMMYT and IITA have been working for over 10 years with national agricultural research institutes to adapt these breeding techniques to SSA. As a result, over 50 new maize hybrids and open-pollinated maize varieties have been developed and provided to seed companies and NGOs for dissemination, and several of them have reached farmers' fields. These drought tolerant maize varieties produce about 20-50% higher yields than other maize varieties under drought. From the biological point of view, we see at this stage no limit to build even stronger resistance to drought into maize varieties adapted to farmers' conditions in SSA. Also, a much greater number of farmers could benefit from existing drought tolerant maize varieties, provided the seed is made available and farmers learn about these varieties.

Vision
The vision of the Drought Tolerant Maize for Africa (DTMA) Project is to significantly scale-up efforts to reach a greater number of poor farmers in SSA with maize varieties that have increased levels of drought tolerance. Indeed, over the next ten years our ambitious goal is to generate maize varieties with 100% superior drought tolerance; increase productivity under smallholder farmer conditions by 20-30%; and reach 30-40 million people in SSA.

How will all this be achieved?
The discovery, enhancement and delivery of drought tolerant maize varieties to farmers can be visualized as a pipeline, starting from accessing new sources of drought tolerance from among the world's genetic resources, through strategic germplasm enhancement targeted at smallholder farmers' maize production environments in SSA, to in-country variety testing and release, and seed dissemination to target beneficiaries.

DTMA will focus on improving, accelerating and enlarging the entire drought tolerant maize variety development and delivery ***pipeline*** *targeted at SSA, including removing institutional bottlenecks for rapidly scaling up and out to reach 30-40 million people over a 10-year time frame.'*

Source: DTMA website (emphasis added).[32]

The DTMA is a 'five year project with a ten year vision' which began in 2006. While it draws on experience and materials from the AMS, the emphasis has shifted to drought tolerant (DT) germplasm developed for temperate zones (though a partnership arrangement with Hohenheim University in Germany); and

[32] http://dtma.cimmyt.org/ (10th April 2009).

to the transfer of new breeding tools, including marker-assisted selection (MAS) to national partners, including NARS and seed companies.[33] Nevertheless, it maintains an established international division of labour agricultural research, in which international centres (such as CIMMYT) develop materials for transnational 'mega environments', which NARS (and other national partners) then adapt for a broader range of nationally-defined agro-ecological zones. In Kenya, for example, while CIMMYT scientists are developing materials for three mega-environments; national scientists are tasked with adapting some or all of these materials for six agro-ecological zones in Kenya. As one national scientist pointed out:

> This [relates to] the history of the CGIAR centres … [based on] the idea that it was possible to breed for mega environments from one location. In a way that's not true, Kenya … has six clearly demarcated environments.[34]

For national scientists, however, the question of site specificity does not stop at the six identified agro-ecological zones that currently structure national breeding programmes, for two reasons. Firstly, increasing climate variability and uncertainty is leading national scientists to question whether six zones are sufficient to capture the increasingly diverse nature of agro-ecosystems throughout Kenya. Secondly, while it may be possible to aggregate agro-ecological factors into a manageable number of 'zones', this is not possible for the diverse user systems within which, it is envisaged, the new varieties will ultimately be adopted.[35]

While CIMMYT scientists acknowledge both the inherent diversity of the maize crop and the challenges of responding to more site-specific patterns of rainfall variability (as opposed to mean shifts in temperature and rainfall), the question remains, however, as to whether the 'mega-programme' model allows scientists sufficient room for manoeuvre to respond to these cross-scale challenges. The framing of the DTMA programme in terms of streamlining a technology supply 'pipeline' in order to achieve 'impact at scale' suggests that the space for more reflexive practice is being reduced rather than expanded. This is likely to discourage the practice of farmer participatory research which, in its current, rather limited form, the 'mother and baby model', is increasingly sidelined.[36] It appears that, while the SADLF and AMS projects 'opened up' breeding for stress environments to new ideas and approaches, under large scale initiatives like the DTMA the system is 'closing down' again around an established institutional-procedural *status quo.* Yet this issue is far from settled, since the very idea of the mega stress environment is still a matter for debate among crop scientists (Blum, 2006).

[33] Interview, CIMMYT, February 2009.
[34] KARI scientist, February 2009.
[35] Interviews, CIMMYT and KARI, February 2009.
[36] Interview, CIMMYT, October 2008.

Water-Efficient Maize for Africa (WEMA)

Shortly after funding the DTMA, the BMGF agree to fund another research initiative, the Water-Efficient Maize for Africa (WEMA) project.[37] While involving some of the same actors, in particular CIMMYT and NARS (including KARI), the project differs from DTMA in important ways. Firstly, the technical focus of the programme, which features transgenic materials donated, royalty free (within certain parameters) from the Monsanto company, for introgression into local materials (such as those developed under the DTMA project). Secondly, a novel institutional arrangement places a public-private partnership, the African Appropriate Technology Foundation (AATF) in the key role of technology broker, negotiating and mediating the relationships between the BMGF, Monsanto and public breeding institutions such as CIMMYT and KARI.[38]

Thirdly, with the technical focus on transgenic materials and crops, there is a clear emphasis on influencing the development of 'enabling' national regulations that facilitate the field testing and release of the varieties once they are developed. In this case, the Biosafety Bill that was recently passed by the Government of Kenya[39] represents an important step for the future of the project. The following text from a concept note placed on the AATF website (see box 8) is unambiguous about the framing of the problem, and solution, around three key principles: the inherent scale neutrality of a solution (in this case, based on biotechnology) built into the seed; the need for more 'enabling' regulatory frameworks and the appropriateness of a consumer choice model to meet farmers' diverse needs.

Box 8: Water-Efficient Maize for Africa: Framing the problem

'One of the greatest attributes of biotechnology is its ***scale-neutral applicability.*** The power of the technology is delivered through a seed that can be grown by any farmer, regardless of their operations and farm size, without additional equipment or large capital investment. Smallholder farmers around the world make up 90% of the customer base using these products, demonstrating the scale neutral value of the technology.

Unfortunately, the vast majority of farmers in SSA have not even had the opportunity to witness field trials of biotechnology products. This "technology gap" is largely due to a ***lack of science-based regulatory frameworks*** that would allow testing and evaluation of new agricultural products and reliable delivery systems to reach resource poor farmers. It means that the most

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37 http://www.aatf-africa.org/aatf_projects.php?sublevelone=30&subcat=5 (10th April 2009).

38 WEMA partners include NARS from Kenya (KARI), Tanzania, Uganda, South Africa and Mozambique.

39 http://www.biosafetykenya.co.ke/bio-act.php (6th October 2009).

vulnerable African farmers fall further and further behind their counterparts in the developed world. Unless efforts are made now to begin establishing functional regulatory capacity and equipping seed delivery systems, it is unlikely that farmers in SSA will be given the choice to benefit from drought tolerant (DT) technology without an additional decade or more of sequential efforts after its launch elsewhere in the world.

Enabling access to the DT product through an approach that **maximizes *farmer choice*** is a major long-term goal of this project. The project is intended to target the vast majority of mall-scale, resource poor farmers in the partner countries. Supporting their transition to use BMPs and access to hybrid seed and extension services will be critical to ensure they realize the maximum benefits of the DT trait. Similarly, support to strengthen the local seed industry to produce quality hybrids containing the DT trait in local varieties will be important to ensure farmer choice. Most local seed companies currently lack the expertise and facilities necessary to manufacture seed of the quality and volume anticipated. The seed must be high quality to ensure that the DT trait is expressed effectively and uniformly across a stand [field] of maize, and high volumes are likely to be required as farmers realize the benefits of the trait and come to expect it as a "base" improvement in all germplasm.'

Source: 'Combining Breeding and Biotechnology to Develop Water Efficient Maize for Africa (WEMA): Concept Note', available at AATF website (emphasis added).[40]

3.2 Extending The Maize System: streamlining the pipeline?

The WEMA and DTMA programmes share certain basic assumptions. Both are structured around an accepted international division of labour in agricultural research in which CGIAR centres produce widely applicable technologies which cascade down through national programmes, which are responsible for adaptive research, to farmers as 'end users'. This structure is underpinned by an interdisciplinary hierarchy headed by plant breeding (and now also genetic engineering), the discipline best equipped to build scale-neutral solutions (able to bypass 'institutional bottlenecks') into the seed. At the same time, WEMA is a point of departure in a number of respects. As mentioned earlier, CIMMYT is not the institutional 'hub', as in the case of DTMA and the AMS. A new type

[40] http://www.aatf-africa.org/aatf_projects.php?sublevelone=30&subcat=5 (10th April 2009, emphasis added).

of institution, a public-private partnership, AATF, is playing the central role of ‘technology broker’ in securing access to proprietary technologies.

Given that the programme centres on the transfer of transgenic technologies and materials, there is a clear push for ‘science-based’ regulatory frameworks that will ‘*allow* testing and evaluation of new agricultural products and reliable delivery systems to reach resource poor farmers’ (emphasis added), in other words, a framework that would enable the programme to achieve its goals.[41] In the words of one project representative: ‘the regulatory climate will have to be permissible’[42] A key stumbling block has been the national biosafety bill, the centre of a polarized national debate over recent years, which was finally passed in February 2009. However a number of questions remain around its implementation, particularly in the case of maize. As a cross-pollinated crop grown on small-holdings across Kenya it is still uncertain how the required 400m isolation barrier is to be enforced[43] This ambiguity is reflected in the following quote from a representative from one of the programme partners, the Monsanto Company:

> Once you have the Biosafety Bill, it’s like any other seed…. except for gene flow. …. no way to stop that, it will definitely flow … may not be clear now. But we are charting new ground, developing … for four or five years ahead.
>
> [Regarding] co-existence issues… discussions haven’t taken place yet … not part of the Biosafety Bill. But regulations need to be pragmatic … *that 400m barrier will have to be reviewed.*[44]

Meanwhile, AATF representatives see their flagship ‘*Strigaway*’ project as providing the template for the future ‘deployment’ of the outputs of the WEMA research.[45] In particular they envisage a key role for private agro-dealers in disseminating the technologies and related advice. However, while useful lessons may be learned from the technology-driven introduction of *Strigaway* technology (a chemical seed coating developed to protect the plant against *Striga*, or witch weed), these may have limited relevance to a transgenic product several years away from deployment, and for which the development of institutional arrangements are still at a very early stage. Given these complexities, it is questionable whether agro-dealers could substitute for an appropriately trained, agricultural extension service in guiding farmers through a maze of decisions regarding the adoption of the new technologies and their integration into diverse farming systems:

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[41] Interview, AATF, May 2009.
[42] Interview, Monsanto, November 2008.
[43] Interviews, Ministry of Agriculture and Monsanto, November 2008.
[44] Interview, Monsanto, November 2008 (emphasis added).
[45] Interviews, AATF, November 2008 and May 2009.

> Farmers mix varieties. They may be shy to tell you [but] they are growing second generation and third generation hybrids. [In the case of GM varieties it is a question of] sustainably managing germplasm once released.
>
> We need to train extension workers. Implementation is the issue. This will complicate the life of the small-scale farmer – first hybrids, now GMOs. Once the bill is passed, the floodgates will open.[46]

What options exist outside of the formal maize sector? As discussed in section 2, informal seed systems play an important role in sustaining farms and livelihoods in areas such as Sakai. At present, however, locally selected seeds can only be saved, used and exchanged informally. Specifically, it is not permissible to bag local seeds and sell them at the local market, for example, since under Kenyan law only fully certified maize seed may be sold. As a KEPHIS representative explained, as Kenya's most important crop:

> …maize is everything. If there's no maize there is hunger. Maize is [therefore] under compulsory certification. For any maize seed to go to market, it must undergo complete certification.[47]

Nevertheless, he also acknowledged that:

> On seed selectors... the law is silent. But we know they are there. They play an important role in food security.[48]

These insights bring us back to discussions, presented earlier in this paper, around formal and informal seed systems and the line that is drawn between them. Farmers in Sakai have to respond, not only to immediate and localised incentives and pressures, but to their assessment of complex dynamics that cross multiple spatial and temporal scales. In other words, they have to make decisions in the face of, not only calculable risks, but uncertainty, ambiguity and even ignorance (See figure 4). Faced with balancing these multiple types of incertitude in their daily lives; farmers *choose* elements of formal *and* informal systems in ways that enable them to tap into sources of social and technical diversity (see figure 5). It is this precarious balance that may be undermined by linear approaches that seek to extend the reach and coverage by one system at the expense of multiple others.

[46] Interview, KEPHIS, November 2008.
[47] Interview, KEPHIS, November 2009.
[48] Interview, KEPHIS, November 2009.

Figure 4: Forms of incertitude[50]

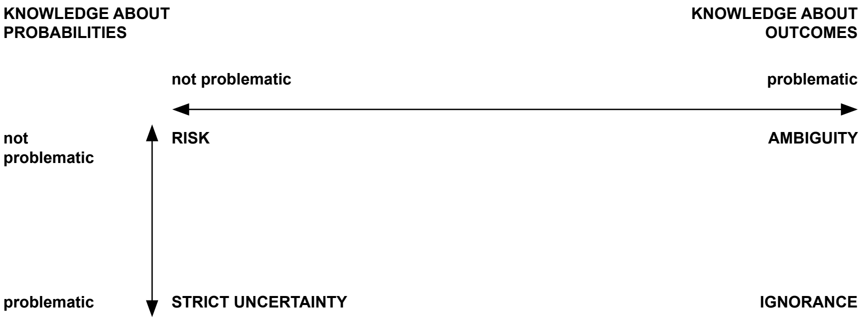
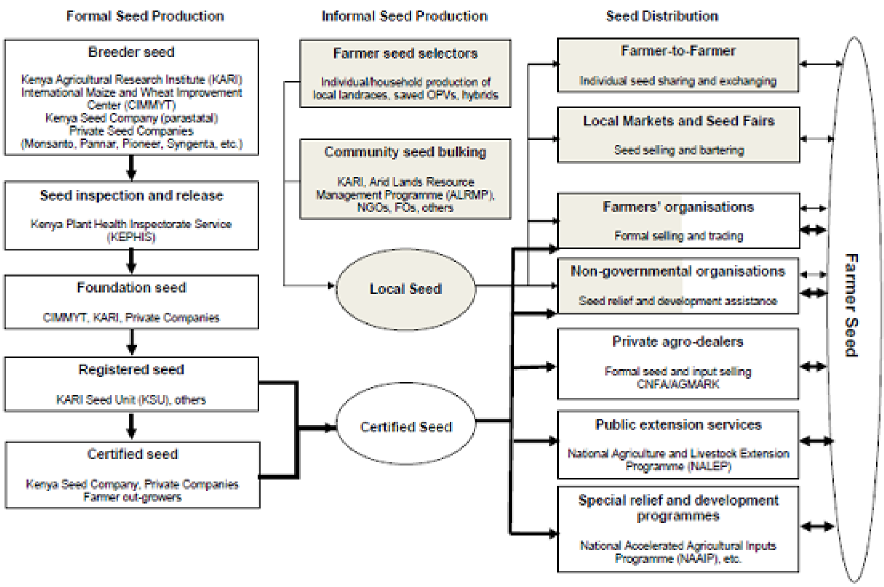


Figure 5: Formal and Informal Maize Seed Production and Distribution Systems in Kenya



[50] Taken from Leach et al. (2007).

Beyond 'lock-in': technology, resilience, diversity

Kenya is recognised within Sub-Saharan Africa for having a well established formal seed sector, and, as such, is seen as a model for other countries in the region to follow. The Kenyan Plant Health Inspectorate (KEPHIS) in particular, is held up as providing a 'gold standard' for seed regulation in Africa.[52] The role of KEPHIS, however, must be placed in the context of a triumvirate of national institutions that dominate the formal (in particular the maize) seed sector in Kenya – the parastatal Kenya Seed Company, KARI and KEPHIS. Kenya Seed, in particular, dominates the profitable market for seeds to be cultivated at high-altitudes.[53] As a result, 'there is a clear line between East and West'[54] in the maize seed industry in Kenya, which has prompted transnational private seed companies to target 'the Katumani market'[55] in a loss-lead strategy to break open what they regard as a far from liberalised market. Initially champions of 'self-regulation', seed companies have become reluctant to make the investment this change would require, preferring to wait and see if the market changes in their favour. It is in light of these dynamics that arguments in favour of a greater role for the private sector in extending 'choice' to poor farmers in drought-prone areas warrants more critical examination.

This paper questions a now widely-shared expectation that an extended network of private providers will form the primary channel for seed (and other input) dissemination and advice throughout Kenya, from two perspectives. Firstly, the proposal rests on a broader set of assumptions about the benefits of extending the coverage of the formal seed sector, presumably at the expense of a reduced role for the informal sector. This extension of coverage is envisaged in terms of the 'trickle down' of practices, developed in and for the 'grain basket', to the West of the country, towards the drought-prone regions of Eastern Kenya - so completing a 'pipeline' that may, at some point in the future, deliver new drought tolerant maize varieties to poor farmers in the Eastern drylands. Evidence presented in section 2.2 however, suggests that any erosion of local seed systems in those areas could leave members of communities such as those in Sakai more rather than less vulnerable, closing down alternative pathways *within* maize. Secondly, it is modelled solely on maize agriculture (and notably for high potential maize growing areas) and is unlikely to support the dissemination of alternative (often tellingly referred to as 'orphan') crops, particularly vegetatively propogated crops such as sweet potatoes, which might otherwise provide the basis for sustainable pathways out of maize.

As discussed in the introduction, attempts to promote alternative crops at local levels are undermined by national food system dynamics which neither assure

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[50] Interview, KEPHIS, November 2009.

[51] Interviews, Pannar and Monsanto, November 2009.

[52] Interview, Pannar, November 2009.

[53] Ibid. 'The Katumani market' refers to the KARI station mandated to breed maize varieties for drought-prone areas.

access to affordable maize meal, nor provide reliable markets for crops which might otherwise have provided farmers in Sakai with pathways out of maize agriculture. In this context, Sakai farmers persevere in planting a crop which typically provides a harvest for just two or three out of every ten years.[54] One option, discussed earlier in this section, is to bypass those dysfunctional system dynamics with a research programme that builds resilience to drought into the maize seed itself, by developing drought tolerant and water efficient varieties. However, while such programmes seem able to circumvent 'institutional bottlenecks', those approaches assume a linear process of 'scaling up' that ignores or discounts the complexities involved in adapting materials developed for large-scale 'mega' environments to diverse agro-ecological and socio-economic user-systems in different parts of Kenya.[55]

Figure 6 shows four different dimensions of 'sustainability', which map on to the four types of incertitude presented in figure 4. While 'mega' breeding programmes and linear 'pipeline' approaches address sustainability, they do so in a restricted sense, which assumes that the only forms of incertitude are calculable risks and events can be predicted or controlled. It is simply a matter of shifting from one stable trajectory to another. However, while global warming and climate change may justify long term investments in breeding for intractable traits such as drought tolerance, these programmes do not address the more localised and uncertain dynamics of variability and seasonality. While key to building resilience at the local level, these dynamics are unlikely to be addressed by generic technologies designed for linear scaling up processes. In a departure from system models that emphasise the criterion of stability (Erikson, 2008, Conway, 1987); Howden et al (2008) stress the importance of addressing variability at the appropriate scale, articulating the challenge as follows:

> Management of variability happens at smaller spatial scales, requiring research pertinent to those scales (from crop to region, modified by institutions etc), but at the same time we want to maximise comparative learning from these studies and to account for global linkages and feedbacks (Howden et al, 2008: 28).

[54] Interview, KARI, February 2009.
[55] Interview, KARI, January 2009.

Figure 6: Dynamic systems properties across time (temporality) and origin (provenance) [56]

Large scale programmes based on plant breeding and strengthening input supply chains rely on a consumer choice model that assumes that an expanded range of varieties, while not developed in direct response to specific, local agro-ecological conditions, will nevertheless map onto existing agro-ecological and socio-economic diversities. In this case, variety (or 'category count') is assumed to approximate to diversity, understood here as involving genuine disparity between options (cf. Stirling, 2007). While questionable in itself, this set of assumptions becomes yet more problematic in light of cross-scale challenges that, as Howden points out, arise when this diversity is combined with locally specific and unpredictable variability in climatic conditions. It is in these increasingly uncertain times that farmers need, more than ever, to be able to draw on different forms of technical and social diversity (cf. Eakin and Wehbe, 2009) rather than see such avenues closed down. The following discussion highlights examples of alternative pathways in and out of maize which might lead to more resilient and robust livelihoods (rather than relying on stability), while showing the challenges they face in the context of prevailing institutional arrangements.

Alternative pathways within maize?

There have been attempts to bridge the formal and informal maize seed systems in innovative ways. Box 9 highlights an example within the GoK Arid Lands Resource Management Project (ALRMP II) project.

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[56] Taken from Leach et al. (2007).

Box 9: 'Informal assisted' seed bulking

In 2006 a group of 40 farmers were selected to participate in a seed bulking initiative, as part of the GoK Arid Lands Resource Management Project (ALRMP) under the Ministry of State for the Development of Northern Kenya and other Arid Lands, based in the Office of the Prime Minister and funded by the World Bank.[57]

As the agricultural officer responsible for the project at that time explained, the main challenge in this area regarding maize farming is 'to get farmers to have a basket of varieties so that at no time will they have a zero harvest'. In this area, farmers have a 'bumper harvest' approximately one year in five. In other years they have drought and no harvest. While the initiative involved a range of crops, farmers were particularly interested in the maize varieties – the drought escaping KCB and DLC varieties (produced at KARI's Katumani station) as well as the local *Kikamba* variety. As he explained: 'farmers never replant the same seeds… they plant composites. By the time they have harvested… [the maize] … has already cross-pollinated … have to go back to KARI to buy more seeds. In this district … 70% of farmers use local seeds'.

There are three types of seeds: certified – 'out of reach for most farmers in Sakai', informal (saved/exchanged local seed) and 'informal assisted'. The project was located in this third category. Farmers were selected, organised and trained to multiply the KCB seed. At harvest, they would return a portion of the seed to the project (for distribution to a further 40 participants) and the rest was theirs to use, exchange or sell. The only restriction was that they could not bag and sell the seed at the market.

In its first year, the project was a resounding success. However in subsequent years this success has not been repeated. There are a number of reasons for this. First, the 2006/7 season was a year of good rains and the farmers enjoyed a bumper harvest. The following two years were marked by drought. In 2008/9, for example, the 'short rains' (the most important of the two rainy seasons in Sakai) lasted only four days. Second, 'scaled down' weather forecasts for the area (under another component of the ARLMPII) predicted good rains in all three years. Notably, in 2007/8 and 2008/9, influenced by these positive forecasts, decided to maximise gains by planting hybrids (instead of the early maturing but lower yielding KCB). In the event they had no harvest. Third, plans to construct a seed bank encountered problems so some saved seed was lost.

[57] http://www.aridland.go.ke/inside.php?articleid=441 (9th September 2009).

However, there was an additional problem which would have dogged the project, even if these other difficulties had not arisen. Throughout the project there was an expectation shared by project staff, community leaders and the participants themselves that, were the initial pilot to prove successful, the farmers participating in the bulking project would be awarded contracts with KARI for seed production. Given the strict certification processes overseen by KEPHIS, however, the likelihood that such contracts would be awarded to such small-scale farms was highly unlikely.

Source: Interviews with project staff and community leaders, Sakai, October 2007 and February 2009.

The Sakai seed bulking initiative set out to bridge informal and formal seed systems in a particular way, bringing an informal system closer to the formal system. On reflection this seems to have been an ambitious goal. This case highlights a crucial link between regulatory and innovation pathways. As discussed in previous sections, current regulatory systems constrain alternative innovation pathways that in reality co-exist with the technology 'pipeline' linking the products of large scale breeding initiatives and private companies with farmers via a network of private retailers.

Alternative pathways out of maize?

The following case (presented in box 10) highlights some of the opportunities and challenges faced by a relatively wealthy farmer in Sakai attempting to diversify out of maize farming.

Box 10: Pathways out of maize?

Timothy lives with his wife and two daughters, both in secondary school, and his adult son, daughter-in-law and four grandchildren. They live on family land of 12 acres, which was shared with his brother, so they each have 6 acres each. At present he has four acres under cultivation, of which two acres is planted with maize. He also grows beans, pigeon peas, finger and pearl millet, sorghum, cowpeas, green grams and fruit trees. At the end of the farm is a river, where he plants dry season vegetables such as tomatoes, cabbages and kales. The remaining land has been leased to distant relatives who came to him for help three years ago. Timothy comes from a wealthy family; his father once owned 100 heads of cattle and his grandfather, over 400. He points to the hill opposite, he also owns land there, which has been subdivided and leased to a number of farmers.

In 2006 he sold five of his eight cattle to pay his daughter's school fees. Now, with only three cattle, he did not have enough manure, and this caused the drop in yield between 2005-6 and 2006-7. His daughter excelled in her

> examinations and was invited to attend secondary school as a boarder, and he did not want to discourage her. He has two adult daughters who, like him, did not graduate from secondary school and they now work in Makueni town as shop assistants, but their salary is too low to help the family. So now he invests his hopes for the future in his younger daughters, that they might complete their schooling and be successful. He believes that daughters are more likely than sons to think about the family, so he is happy to make sacrifices to finance their education.
>
> In the future, he plans to gradually replace maize as his primary crop with fruit trees. He was one of the early experimenters with tree planting, since he has a water source on his land. He also grows traditional crops, millet and sorghum, but only he and his wife eat them. The children complain if they are given pearl millet, saying it is like eating soil. But he remembers the previous generation who were used to eating these crops, it seemed they were stronger and lived longer. He remembers old people of 100 years who were still very strong. Since people started eating maize they seem to age faster.
>
> *Source: Interview with 'rich'[58] farmer, Sakai, December 2008*.

The case presented in box 10 highlights the different ways in which this farmer is attempting to diversify out of maize. Clearly his relative resource wealth – in terms of land, livestock and water supply, have been crucial. In particular, his access to water enabled him to benefit from being an 'early adopter' of grafted fruit tree technology. However, unlike some of the cases presented in section 2, no one in this family has progressed sufficiently far in their education to be in a position to provide a substantial off farm income, which means that, despite his relative resource wealth, this farmer perceives his family as vulnerable. He has therefore chosen to run down his livestock in order to invest in the education of his youngest children in the hope that they will graduate and secure well paying jobs. That a farmer of this standing in the area, a well known experimenter, sees this as the only way to secure a sustainable livelihood in the longer term is indicative of his assessment that his efforts at the farm and community level are a poor match for forces that operate at regional and national levels.

Timothy's story highlights the complexity involved in farmers' everyday decision making that was illustrated by the accounts of different farmers' livelihood choices presented throughout section 2.2. These complex and uncertain dynamics were amplified in recent years by the cumulative effects of post-election violence, unpredictable input (particularly fertilizer) markets and the onset of droughts that have led to a full scale food crisis in the country. According to a recent assessment:

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[58] Wealth ranking by key informants, Sakai, December 2007.

> An estimated 3.8 million people in rural areas are highly to extremely food insecure. […] . While drought is the critical proximate causal factor for the levels of food insecurity, the adverse effects of heightened food prices, livestock disease, and debilitating conflict have caused a precarious decline in food security that may not be reversed quickly, even by above normal rains due to El Niño.[59]

Farmers in Sakai interviewed for this study were well aware of the impact of these events on the livelihood choices open to them. As discussed in section 2.2, crop scientists are quick to point out Sakai farmers ‘shouldn’t grow maize’, yet at the same time they recognise the complex of reasons why maize cultivation is, nevertheless, their best (or least-worst) bet. For Sakai farmers, maize is perceived as the only available form of insurance[60] in an uncertain world. In this context, area-based initiatives which seek to promote alternative pathways within maize (for example seed bulking and cereal bank initiatives) or out of maize (for example the promotion of dryland food crops, domestic horticulture and tree planting) in areas like Sakai face considerable challenges.

3.3 Multiple innovation pathways: a typology

The next phase of the STEPS maize project will explore, with various stakeholders in Kenya, ways of ‘opening up’ the debate about ‘pathways in and out of maize’ (cf. Stirling et al., 2007). In particular, the project will explore the various *innovation* pathways that represent perspectives of particular actors and/or institutions and the way in which they frame the problem. Just some of these multiple innovation pathways are summarised in the typology presented in figure 7. The two axes of this typology are drawn from figure 2 – diversification (into other crops) and intensification (the extent to which commercially available inputs such as seeds and inorganic fertilizers are used in preference to - or in combination with - local seeds and recycled organic nutrients such as manure and compost). For the purposes of creating a typology, these two axes have been divided in terms of ‘low maize vs. high maize’ (diversification) and ‘low vs. high external input’ (intensification).

The nine innovation pathways identified in figure 7 can be found, alone or in various combinations, in the farmers’ and institutions’ responses and innovations that have been presented in boxes throughout this paper. Each

[59] http://www.fews.net/docs/Publications/Kenya_FSU_August09_final.pdf (5th September 2009).

[60] Interview, KARI, February 2009.

pathway incorporates particular actors' (or groups of actors') views on how best to enhance the resilience of farmers' livelihoods in marginal, dryland areas like Sakai. Furthermore, each operates – or envisages operating – at a particular scale. For example, while pathways 1, 2 and 3 operate at the local level, drawing on local institutions and resources, pathways 4, 5 and 6 often form part of an area-based response focused on the needs of a particular agro-ecological zone (for example the UNEP/GEF funded 'Increasing Community Resilience to Drought Project' and the Government of Kenya's ARLMPII). Nevertheless, these programmes, and in particular activities that fall within 'pathway 4', have faced challenges in the context of national food system dynamics that effectively discourage farmers from diversifying out of maize (as discussed in section 2). Finally, 'pathway 8' forms part of a national (and international) vision for revitalising agriculture which, as discussed earlier in this section, relies on assumptions that models for and from Western Kenya will ultimately 'trickle down' to the Eastern part of the country, in ways that may have implications for social and agro-ecological diversity in the region.

Figure 7: Pathways in and out of maize: a typology[61]

		Diversification	
		Low maize	**High maize**
Intensification	**Low External Input (LEI)**	**1. Alternative staples for subsistence** Farmers diversify away from maize to alternative dryland staple crops (also known as orphan /traditional /indigenous crops) such as sorghum, millet, cassava, sweet potato, pigeon pea, cowpea and others. These crops are increasingly grown alongside maize on the farm and are used mainly for household consumption (self-provisioning). Local varieties of alternative crops are used with minimal or no external inputs (certified seeds, chemical fertilizers, etc). **2. Alternative staples for market** Farmers diversify away from maize to alternative dryland staple crops such as sorghum, millet, cassava, sweet potato, pigeon pea, cowpea and others. Maize is increasingly purchased for consumption with the proceeds from the sale of alternative crops. Local varieties of alternative crops are used with minimal or no external inputs (certified seeds, chemical fertilizers, etc).	**3. Local improvement of local maize seed** More farmers learn to select and multiply local varieties of maize seed for local use (planting on the local farm or sale/exchange with other farmers). Local varieties of maize are used with minimal or no external inputs (certified seeds, chemical fertilizers, etc).

Figure 7: Pathways in and out of maize: a typology[62]

		Diversification	
		Low maize	**High maize**
Intensification	**Low External Input (LEI)**	**4. Assisted seed multiplication (alternative crops)** Farmers are assisted in multiplying seeds of available improved varieties of alternative dryland staple crops such as sorghum, millet, cassava, sweet potato, pigeon pea, cowpea and others. These seeds are used for planting on the local farm or for sale/ exchange with other farmers. Varieties are provided to farmers and assistance is given in seed multiplication, farming techniques, etc.	**5. Assisted seed multiplication (maize)** Farmers are assisted in multiplying seeds of available improved, open-pollinated, drought-tolerant /drought-escaping maize varieties. These seeds are used for planting on the local farm or are used for sale/exchange with other farmers. Varieties are provided to farmers and assistance is given in seed multiplication, farming techniques, setting up cereal banks, etc.
	High External Input (HEI)	**6. Individual high-value crop commercialisation** Farmers diversify into high-value/high-risk horticultural crops such as tomatoes, onions and fruit trees. Maize is gradually replaced on the farm by these high-value crops. Maize is increasingly purchased for consumption with the proceeds from the sale of high-value crops. Crops are grown with external inputs (certified seeds, chemical fertilizers, etc.) and require access to a water source and/or water storage techniques. **7. Group-based high-value crop commercialisation** Farmers form groups to diversify into high-value/high-risk horticultural crops such as tomatoes, onions, fruit trees. Maize is gradually replaced on the farm by the high-value crops. Maize is increasingly purchased for consumption with the proceeds from the sale of high-value crops. Crops are grown with external inputs (certified seeds, chemical fertilizers, etc.) and require access to a water source and/or water storage techniques.	**8. Commercial delivery of new maize varieties** Farmers purchase new hybrid maize seed varieties such as drought-tolerant hybrid maize from commercial dealers such as private agro-dealers and stockists. Maize is grown on the farm for local consumption and/or sale. These crops are grown with external inputs (certified seeds, chemical fertilizers, etc.). **9. Public delivery of new maize varieties** Farmers purchase new hybrid maize seed varieties such as drought-tolerant hybrid maize from public delivery mechanisms. Maize is grown on the farm for local consumption and/or sale. These crops are grown with external inputs (certified seeds, chemical fertilizers, etc.).

[61] Authors' elaboration.
[62] 'Informal assisted' is a term used within ARLMPII (see box 9).

4. CONCLUSION: CLIMATE CHANGE AS AN OPPORTUNITY?

While the effects of drought are very much a reality for people in Sakai, and have been for many years, the issue of climate change is less clear. While Sakai community members have been 'sensitised', through participation in successive development interventions, to the existence of climate change, national meteorological data collected by the project so far[63] appears to confirm the view of scientists interviewed for this study – that the periodic droughts experienced in areas like Sakai follow a familiar and largely predictable pattern. As one scientist explained:

> The impacts of climate change can only be picked at the global scale, but at local scale it's very difficult. [So we end up telling them] "Things are changing all over the world and *you will be the most affected!*"[64]

Nevertheless, debates and uncertainty about the existence and effects of climate change in Kenya present an *opportunity* to challenge conventional wisdoms and established practices. This paper has highlighted some of the challenges involved in facilitating the exit of farmers in areas like Sakai from maize farming into crops more conducive to dryland conditions. As long as they remain uncertain about the reliability of markets for such produce, as well as the availability and affordability of maize and unga for their own home consumption, they are unlikely to make such a shift. Furthermore, planting materials for root crops such as sweet potato and cassava are not attractive to commercial agro-dealers, so serious attempts to promote alternative crops would require a rethinking of the agro-dealer model, or at least the support of complementary extension channels, to disseminate such crops.

Of particular concern, in Sakai and elsewhere, are the locally specific variations in the timing and intensity of rainfall that are more difficult to 'aggregate up'. This paper has highlighted the need for institutional as well as technical innovations if current interventions are to enhance rather than undermine resilience in the face of climate variability and uncertainty. Despite their use of a language of adaptation and resilience, initiatives that rely on classic 'mega programme' and linear 'pipeline' innovation (and associated regulatory) approaches remain locked into a linear, risk-stability management model that is unlikely to match, let alone enhance the adaptive capacity of households and communities in marginal

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[63] National meteorological data was collected for the three sites. This data and analysis is incomplete at this stage – however an initial review of data relevant to the Sakai area appears to concur with the interpretations of scientists interviewed for this study.

[64] Interview, KARI, February 2009 (original emphasis).

environments. In particular, interventions focusing on strengthening and extending the formal maize system at the expense of local, informal systems are in danger of undermining those sources of diversity on which people in different localities need to draw if they are to build livelihoods that are both resilient to shocks and robust in the face of longer term stresses.

Promoters of programmes such as DTMA and WEMA have been successful in seizing the opportunity presented by climate change debates to frame a complex problem around the type of solution they are able to offer. This paper argues that those who wish to advocate alternative pathways within maize (recognising multiple systems) and out of maize (into other crops and livelihood options) can do the same. In this case, rather than focus on a single maize system, a more promising way forward may be to think in terms of 'maize *in* a system' – recognising the multiplicity of socio-economic and agro-ecological systems in which maize plays different roles. This conceptualisation, we argue, provides a more helpful starting point for exploring potential pathways in and out of maize.

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APPENDIX

Maize in Kenya: lessons from Tegemeo panel data

The data presented in this appendix draws on time series panel data collected over a ten-year period (1997-2007) by the Tegemeo Institute, Egerton University for three sites representing low, medium and high-potential agricultural areas.

Part 1: Demographic and economic trends in three contrasting research sites

The Tegemeo panel data set was collected in 1997, 2000, 2002, 2004 and 2007. The initial panel consisted of 1,594 households which were sampled from 22 districts around the country.[65] The panel data subset used in this study provides helpful insights into the trends in maize production activities and socio-economic and demographic characteristics of a total of 313 sample households in the three study districts of Kakamega (N = 127), Nakuru (N = 114) and Makueni (N = 72). Table 1 (below) summarises demographic data for the three sites, showing, in particular, education, gender and age of the household head, off-farm income status of the household, household size and dependency ratio, and value of household assets.

[65] The sampling was done based on 1989 Demographic Survey of Kenya. The country was divided into eight Agro Regional Zones and 22 districts were selected within each zone. Each district was divided into divisions, locations and sub-locations and then villages. The population of each district was taken into account during the sampling. Some divisions were randomly selected in a way that incorporated the diversities that were inherent in each district. A similar sampling process was carried out at the division, location, sub-location and village level. For the selected villages and with the help of the administration and key informants, a list of all household units within the village was generated. From this list, the required number of households was randomly selected.

Table 1: Household demographic and economic characteristics

Education Level of household head (% of household)						
District	No formal education	Primary	Secondary	College	University	Total
Makueni	9.7	56.9	27.8	4.2	1.4	100
Kakamega	19.7	52.8	22.0	4.7	0.8	100
Nakuru	26.0	45.8	24.0	3.1	1.0	100
Total	19.3	51.5	24.1	4.1	1.0	100

Gender of household head (% of households)			
District	Male	Female	Total
Makueni	77.8	22.2	100
Kakamega	78.0	22.0	100
Nakuru	79.2	20.8	100
Total	78.3	21.7	100

Off-farm income status of household (% of households)			
District	Without off-farm income	With off-farm income	Total
Makueni	4.2	95.8	100
Kakamega	8.7	91.3	100
Nakuru	6.3	93.8	100
Total	6.8	93.2	100

Mean age of household head, household size, dependency ratio and household asset value				
District	Age of household head (Yrs.)	Household size (No. of members)	Dependency ratio	Assets value (KES)
Makueni	55	6	0.9	313,578
Kakamega	59	6	0.9	132,652
Nakuru	63	5	0.7	403,422
Total	59	6	0.8	264,925

Notably, most households (93%) in the sample have some form of off-farm income, with Makueni having the highest proportion (96%). This signifies the importance of off-farm earning activities among the rural households. The higher proportion in Makueni is not surprising given that the district is in a lower agricultural potential region compared to Kakamega and Nakuru, leading the majority of the households to augment agricultural incomes with incomes from non-farm activities. This livelihood strategy (and therefore the importance of access to formal education) becomes crucial in semi-arid environments such as Makueni, where agriculture is a highly risk-prone activity.

Table 2 shows total household income for each site, composed of income from crops, livestock, salaries and remittance and businesses activities. The mean annual income is estimated at KES 192,774 for Makueni households, KES 148,707 for Kakamega households and KES 234,581 for Nakuru households, as shown in table 2.

Table 2: Mean annual incomes in Kenya Shillings by study district

Income Source	Year	Makueni	Kakamega	Nakuru
Crop	1997	42,691	45,871	88,096
	2000	70,959	118,096	32,927
	2004	51,747	59,569	105,256
	2007	82,124	93,493	63,519
	Average	61,880	79,257	72,450
Livestock	1997	15,841	16,165	49,867
	2000	24,635	16,025	57,241
	2004	21,191	21,086	70,889
	2007	33,046	30,370	97,276
	Average	23,678	20,911	68,818
Salary and Remittance	1997	83,035	15,086	47,697
	2000	48,156	22,984	33,909
	2004	69,648	29,744	62,078
	2007	73,423	26,226	70,791
	Average	68,565	23,510	53,619
Business	1997	14,382	16,871	16,009
	2000	38,750	32,775	35,872
	2004	55,991	15,845	60,200
	2007	45,475	34,626	46,699
	Average	38,648	25,029	39,695

Income Source	Year	Makueni	Kakamega	Nakuru
Overall	1997	155,948	189,880	159,949
	2000	182,501	189,880	159,949
	2004	198,577	126,243	298,423
	2007	234,068	184,714	278,285
Average		192,774	148,707	234,581

In Kakamega, crop contributes the highest proportion of total income (53%). In Nakuru both crop and livestock are relatively important contributing over 60% of the total household income. In Makueni district, off farm income (i.e. salaries, remittance and business) contributes close to 50% of the income. This may be attributed to risks involved in rain-fed farming in Makueni districts, which lead farmers to diversify to other income generating activities.

Part 2: Focus on maize

The following data focus on maize in these three sites, its role in and contribution to farms and livelihoods (for different income groups) and related trends in maize production and marketing.

Contribution of maize to gross crop value

Across the three study districts, nearly 100% of sample farmers planted maize over the panel period (1997-2007). The contribution of maize to gross crop output across the panel averages between 20-43% (table 3). Maize is a very important crop in Nakuru District contributing an average of 43% of the gross crop output value. However, in Nakuru, maize contribution is gradually declining, probably because of emerging high value crops such as fruits and vegetables. In Kakamega District, maize contributes an estimated 37% of the total crop value. The percentage contribution of maize is relatively lower in Makueni District compared to the other two districts, accounting for 20%. This indicates that maize is not a major crop enterprise in Makueni in terms of crop revenue. It is important to note that production for the year 2000 was adversely affected by drought, thereby reducing maize production. More recently, maize harvests have been extremely low in Makueni because of an extended drought that has now entered its third year.

Table 3: Percentage contribution of maize to gross crop output

District	1997	2000	2004	2007	Mean
Makueni	22.1	16.5	19.0	22.7	**20.1**
Kakamega	37.8	27.8	46.1	39.8	**37.9**
Nakuru	51.7	40.9	45.4	35.9	**43.4**

Contribution of maize to gross crop value by income level

The contribution of maize to Total Crop Value (TCV) by income quintile across the three regions shows a variation of the importance of maize across the income quintiles. In 1997, maize contributed over 45% of the TCV amongst farmers in the lowest income quintile and 34% for the farmers in the highest income quintile (table 4). This scenario is reflected across the panel period. However, in 2007, the contribution was 39% among farmers in the lowest income quintile and 32% for farmers in the highest income category. The above implies that any environmental or climate change that affects production maize impacts heavily on the low income households, who are usually more vulnerable to food insecurity.

Table 4: Mean percent contribution of maize to total crop value by income quintile

Quintile	1997	2000	2004	2007	Quintile Mean
Lowest	46.6	31.3	43.1	38.6	**39.9**
2	43.4	34.6	38.3	37.1	**38.4**
3	33.7	27.7	36.1	31.8	**32.3**
4	35.0	28.8	40.7	32.1	**34.1**
Highest	34.1	23.9	38.4	32.3	**32.2**

Cultivated land and land allocated to maize farming

The mean cultivated land varies by district, with Nakuru recording the highest cultivated land sizes, followed by Kakamega and Makueni. With an exception of Makueni, the cultivated land sizes in Kakamega have declined from 5 acres to 4.5 acres, while Nakuru from 7 acres to 5.5 acres (table 5). This decline could be attributed to sub-division of land within these regions.

Table 5: Mean cultivated land by study district

District	1997	2000	2004	2007
Makueni	2.6	3.0	3.5	3.0
Kakamega	5.1	5.7	4.6	4.5
Nakuru	7.2	8.6	5.5	5.5

There is a general increase in the proportion of land under maize production in relation to the total cultivated area (table 6).[67] This trend mirrors trends in area under maize production nationally. In Makueni, the proportion of area allocated to maize has increased from 57.2% in 1997 to 63.2% in 2007, despite the relatively low yields. In Kakamega, there has been an increase from 48% in 1997 to 52% in 2007, while in Nakuru the proportion of land under maize has increased from 63% to 65% over the same period. This re-emphasises the dominance of maize in Kenyan agriculture, in high, medium and even low-potential areas, raising questions about how and why the crop has gained such prominence, even in localities where it appears to be ill suited.

Table 6: Proportion of area under maize in relation to total cultivated area

District	1997	2000	2004	2007
Makueni	57.2	52.8	55.8	63.2
Kakamega	48.0	46.3	48.9	51.7
Nakuru	62.9	65.2	63.8	64.5

Trends in Maize Productivity

Maize productivity within the three districts has generally increased over the panel period. Not surprisingly, Makueni has the lowest productivity of the three study districts, which could have been attributed to low use of productivity enhancing inputs, such as fertilizer, and unreliable rainfall. Productivity in the higher potential sites of Kakamega and Nakuru is double that of Makueni (table 7).

[67] Includes area under mono-cropped and intercropped maize.

Table 7: Maize productivity (kg/acre) by study district

District	1997	2000	2004	2007	Average
Makueni	297	379	298	506	**370**
Kakamega	514	740	1,014	1,179	**862**
Nakuru	936	388	1,305	798	**857**

Productivity of farmers in the lowest income quintile is 30% lower than those of the highest income quintile (table 8). This could be attributed to the inability by the lower income group of farmers to access the required agricultural inputs (e.g., inorganic fertilizers) and/or their inability to use resource conserving practices (e.g., soil and water conservation techniques) to enhance soil fertility.

Table 8: Maize productivity (kg/acre) by income quintile

Quintile	1997	2000	2004	2007
Lowest	367	377	700	657
2	627	477	784	850
3	492	521	802	1,032
4	591	581	1,192	887
Highest	919	731	1,203	1,038

These figures suggest that interventions seeking to increase maize productivity in complex, diverse, risk-prone environments will need to provide not only improved seeds to poor households, but also support to obtain fertilizers and/or labour to improve soil fertility management practices.

Adoption and Intensity of Fertilizer Use

Fertilizer use in maize production in Makueni and Kakamega Districts doubled between 1997 and 2007. Nakuru District had the highest level of adoption during that period, with nine out of ten households using some amount of inorganic fertilizer (table 9). Despite lower overall adoption rates, the more impressive increases came in the other two districts, Makueni and Kakamega, which saw a two-fold increase in fertilizer use.

Table 9: Adoption of fertilizer on maize by study district

District	1997	2000	2004	2007
Makueni	42.3	52.8	77.5	81.4
Kakamega	37.8	59.8	65.9	81.0
Nakuru	89.5	91.7	93.8	92.6

These apparent high rates of fertilizer adoption can be deceiving, however, as the intensity of use (i.e., the amount of fertilizer applied per acre of land) has either remained constant or declined during the panel period (table 10). Kenya possesses great agro-ecological heterogeneity. While its highland areas are generally suitable for cultivation and are close to urban markets, many parts of the country are semi-arid. While crop production is still important in these areas (e.g. eastern lowlands, coastal areas, western lowlands), the profitability of fertilizer use is not clearly established in most of these semi-arid areas. The lack of irrigation potential and variability of rainfall in most low-potential areas drives down the farm-level profitability of fertilizer use rates in these regions. Thus, it should not surprising that Makueni has the lowest intensity ranging from 14kg per acre to slightly below 25 kg per acre, which is only 30% of the recommended rate of application. However, the rate of application of fertilizer has increased from 14 kg/acre in 1997 to 21 kg/acre in 2007, with a peak in 2000 at 23kg per acre.

Table 10: Fertilizer application rate (kg/acre) on maize by study district

District	1997	2000	2004	2007
Makueni	14.1	23.2	17.5	21.0
Kakamega	76.7	62.9	75.8	78.3
Nakuru	46.3	43.3	46.8	43.3

By contrast, in Kakamega, fertilizer application rate has generally remained high and at or near the recommended rate of 75 kg/acre. However, though Nakuru District has recorded the highest adoption rate of fertilizer, the application rate has stabilized slightly above 40 kg/acre, which is 45% less than the recommended rate. It is likely that the optimal use of fertilizer could be one of the contributing factors of high maize production in Kakamega District.

Disaggregating these figures by income, the analysis also reveals that fertilizer adoption and application are higher among the higher income quintiles. This reinforces the challenge faced by poor maize farmers in Kenya, who are seeking to increase their productivity. Whether one looks at it in terms of adoption rates (table 11) or application rates (table 12), poor farmers use significantly less fertilizer than their wealthier counterparts, in all regions.

Table 11: Fertilizer adoption in maize by income quintile

Quintile	1997	2000	2004	2007
Lowest	32.8	55.9	55.2	67.2
2	50.8	55.9	72.9	86.2
3	52.5	74.6	81.4	91.4
4	64.4	81.4	91.5	89.7
Highest	77.6	74.6	87.9	89.7

Table 12: Fertilizer application rate (kg/acre) on maize by income quintile

Quintile	1997	2000	2004	2007
Lowest	49.1	31.2	35.4	34.0
2	40.8	49.8	41.8	48.7
3	42.1	45.1	43.2	52.6
4	43.9	52.7	59.8	57.4
Highest	64.6	51.8	63.5	65.7

The proportion of households using optimal fertilizer applications (over 50kg/acre) did increase very gradually over the panel period, but it still remains very low. In Makueni, the proportion increased from 1.4% in 1997 to 7.1% in 2007, while in Kakamega it increased from 26% in 1997 to 48% in 2007. However, in Nakuru this proportion has stagnated at 12% of the households.

Maize Varieties

In addition to agro-ecology and fertilizer use, the level of maize productivity is greatly influenced by the variety of maize planted. Table 13 shows that Kakamega District has the highest number of new maize varieties adopted by farmers between 2004 and 2007.

Table 13: Varieties of Maize Seeds by District

Seed Variety	Number of Farmers					
	2007			2004		
	Makueni	Kakamega	Nakuru	Makueni	Kakamega	Nakuru
DK 8071	-	2	-	-	-	-
Faida Seed 650	-	-	-	-	-	2
Fresh core	-	1	-	-	-	-
Indigenous /local type	43	27	15	35	40	8
Katumani	-	-	-	1	-	-
Kinyanya	1	-	-	-	-	-
KS 511	5	4	2	12	2	3
KS 512	-	-	-	-	1	1
KS 513	-	8	1	2	6	2
KS 514	-	-	-	-	1	1
KS 515	-	-	1	-	-	-
KS 611	-	-	1	-	-	-
KS 613	-	2	1	-	2	-
KS 614	-	61	49	1	60	57
KS 6210	-	3	10	-	-	-
KS 6213	-	5	10	-	-	-
KS 622	-	1	-	-	-	1
KS 623	-	2	1	-	2	-
KS 625	-	2	3	-	6	3
KS 626	-	1	3	-	3	1
KS 627	-	1	3	-	3	10
KS 628	-	1	6	-	7	14
KS 629	-	-	8	-	-	-
KS 9201	-	-	1	-	-	-
KS 9401	-	1	-	-	1	1
Pan 67	-	2	-	-	-	-
Pan99	-	-	-	1	-	-
Pan 691	-	4	1	-	-	-
Pan 5195	-	-	-	-	-	1
Pioneer	25	2	-	26	1	2
Punda milia	-	1	-	-	-	-
SCDUMA 43	9	-	-	-	-	-
Western Seed	-	-	-	-	2	-
WS 402	-	1	-	-	-	-
WS 403	-	1	-	-	-	-
WS 501	-	1	-	-	-	-
WS 502	-	9	-	-	-	-
WS 503	-	3	-	-	-	-
WS 505	-	10	-	-	-	-
WS 699	-	-	-	-	1	-
WS 904	-	-	-	-	1	2
TOTA	83	156	116	78	139	109

In total, the number of varieties increased from 17 in 2004 to 26 in 2007 in Kakamega. There has not been a significant change in the number of maize varieties adopted by farmers in Makueni and Nakuru Districts. The increase in the number of varieties adopted for the Kakamega region could be attributed, in part, to the liberalisation of the seed sector. However, most seed companies, such as Kenya Seed, Western Seed and Lagrotech are concentrated in the western region of the country, where many farmers grow maize commercially and therefore where there is the greatest demand for hybrid seeds.

By contrast, although some farmers in Makueni are using improved varieties, approximately 50% continue to plant indigenous/local varieties (highlighted in table 13 on page 13). The community-level studies in Sakai revealed that this was because farmers were either unable or unwilling to purchase improved seeds due to their uncertain availability, their relatively high cost, their intolerance to environmental stresses, such as drought, or other factors that will be examined in more detail in the next section. As a result, nearly all poor farmers in Sakai continue to rely predominantly on their local varieties to a significant degree.

Maize Marketing

Kenya has long pursued the national goal of self-sufficiency in maize as well as other crops. Under this policy, most households were commonly viewed to be net maize sellers who derived their benefits largely from high grain prices. However, from other studies undertaken by Tegemeo Institute and others, it is now clear that the vast proportion of Kenya's rural households are net buyers of maize (cf. Jayne, et al. 2005; Nyoro, et al. 1999).

The findings of this analysis concur with those results. In Makueni, for example, less than 20% of the households sold maize during the survey period (table 14), with only 13% selling on average. Even in zones commonly perceived as grain surplus areas, a majority of households were net buyers of maize. In Kakamega, the proportion of farmers selling maize is over 50%. Nakuru has the highest proportion of farmers (about 70%) who sold maize.

Table 14: Proportion (%) of households that sold maize by study district

District	1997	2000	2004	2007
Makueni	5.6	13.9	19.4	12.8
Kakamega	30.7	45.7	59.8	48.0
Nakuru	78.1	39.6	64.6	67.2

The proportion of maize sold to the total harvest ranges between 5% (Makueni) and 33% (Nakuru) (table 15). This proportion also differs across the income quintiles (table 16).

Table 15: Mean percent of maize sold to total maize harvested by study district

District	1997	2000	2004	2007	District Total
Makueni	2.0	4.4	6.2	8.3	5.2
Kakamega	14.4	21.8	25.7	26.1	22.0
Nakuru	41.5	21.1	51.0	34.0	36.9

Table 16: Mean percent of maize sold to total maize harvested by income quintile

Quintile	1997	2000	2004	2007
Lowest	9.8	6.8	13.6	10.8
2	20.0	15.4	15.9	17.9
3	16.3	18.5	24.0	20.0
4	19.2	17.8	43.4	27.1
Highest	35.8	27.4	49.4	37.9

As the proceeding discussion of the Tegemeo panel data findings highlight, maize remains a vital source of livelihood for most of the rural households in Makueni, Kakamega and Nakuru Districts. Especially important is its dominance as the crucial staple food and the substantial proportion of crop revenue to which it contributes across the three study districts and income brackets.