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Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis

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Abstract Increased productivity of potatoes can improve the livelihood of smallholder potato farmers in Kenya, Uganda and Ethiopia and is required to meet the growing demand. This paper investigates the opportunities for potato system improvement that could result in improved productivity. Through a diagnosis of the potato systems in the three countries on the basis of surveys and stakeholder workshops, seed potato quality management, bacterial wilt control, late blight control and soil fertility management were identified as key technical intervention topics. For effective problem solving in these areas, the functioning of the potato innovation system requires improvement to better deliver the functions of potato marketing as well as knowledge development and information exchange. With use of a 'system failure framework' the shortcomings of the potato innovation system are identified and discussed and options for improvement are suggested.

Keywords Bacterial wilt · East Africa · Innovation system · Late blight · *Phytophthora infestans* · Potato · *Ralstonia solanacearum* · System diagnosis

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Introduction

Potatoes are a source of both food and cash income in the densely populated highlands of sub-Saharan Africa. Through this double purpose, the potato crop plays an important role in the rural livelihood system. Because of high prospects for growth of the market for fresh potatoes (Scott et al. 2000), the commodity could be a good starting point for rural development in sub-Saharan Africa, particularly under current conditions of increased cereal prices in the international markets.

Fuglie (2007) suggests broad fields of potato research and development that could be prioritized in different regions of the developing world. For effective targeting of research and development efforts, a more detailed country- or region-specific analysis of the potato system and its potential opportunities and possible constraints is required. This analysis should not only identify important technological research areas, but should also identify the weaknesses within the innovation system that have deterred and could continue to deter innovation of the potato sector taking place.

Kenya, Uganda and Ethiopia are among the ten African countries with the largest area cropped to potato (FAOSTAT 2006). These countries, however, differ substantially in terms of the integration of potato farmers in the market as well as the structure and functioning of the potato-related innovation system. Together the three countries are representative of a large portion of the potato sector in sub-Saharan Africa.

In this paper the current potato production systems in Kenya, Uganda and Ethiopia are diagnosed. Through a combination of stakeholder workshops [method adapted from Engel (1997) and Biggs and Matsaert (1999)] and two quantitative surveys among potato farmers, the potato production systems of Kenya, Uganda and Ethiopia were characterized and technical and innovation system related constraints that hinder potato productivity were identified. With use of a system failure framework developed by Woolthuis et al. (2005), the strength and weaknesses in the potato-related innovation system in the three countries are revealed. Finally, on the basis of these findings, opportunities for potato system improvement in Kenya, Uganda and Ethiopia are discussed.

Methods

Two surveys were conducted. The first survey examined the potato production practices and technologies of smallholder potato producers, while the second survey was conducted to assess the potato-related knowledge and information system in the subregion. Questionnaires were pretested and adapted before full implementation of the surveys by purposefully recruited and trained enumerators. Data from the surveys were coded and entered by each country team and centrally cleaned for all three countries and analysed using SPSS software. Costs of labour were calculated on the basis of farmer estimates, and opportunity costs for labour were based on the average hired labour cost estimates. Economic analysis calculations were based on average yield figures over all cultivars and seasons, weighed for plot area.

Potato Practices and Technology Survey

The potato practices and technology survey focused on documenting management practices and technology used by potato producers in Kenya, Uganda and Ethiopia. This survey yielded the information on productivity and economics of potato presented in this paper.

In Kenya, data collection took place between 10 and 29 October 2005. After a rapid appraisal of the potato system in Kenya, Meru Central and Nyandarua districts were selected as sample districts as they were considered to best represent the whole of the Kenyan potato production system. A district is an administrative topographical unit which is further subdivided into divisions, locations and sublocations, the last of these being the smallest administrative unit. Six farmers were randomly chosen in half of the sublocations within each location in the sampled districts to get a satisfactory number of sample farmers. The sample households were randomly picked from a list of all farm households in the village, provided by a village elder. In total, 251 farmers were successfully interviewed, 100 in Meru Central district and 151 in Nyandarua district.

In Uganda, the survey was implemented between 1 and 25 November 2005. Kabale and Kisoro districts were selected to represent the potato farming system in Uganda. All four counties and the 25 potato-producing subcounties in Kabale and Kisoro districts were included in the study. One parish was randomly selected from each subcounty and one village was randomly selected within each parish. Six households were picked at random in each sampled village from a list of households provided by a village elder to ensure a sufficiently large and representative sample. In all, 144 farmers out of 150 randomly selected were successfully interviewed. In addition, 89 farmers were randomly picked from selected farmer groups who had participated in earlier potato-related research and development activities.

In Ethiopia, data collection took place between 5 February and 27 March 2007. Three major potato-producing districts (*woredas*) were selected, Jeldu in West Shewa zone, Degem in North Shewa zone and Banja Shikudadin in Awi zone, as a cross-section of potato production in the country. Within these districts, six households were randomly selected within each *kebele* (village), resulting in 220 households that were successfully surveyed. In addition, 116 households of farmers that had participated in activities of the Ethiopian potato development project partner were selected from all participants. In Ethiopia therefore, 336 households were surveyed.

Data from the selectively sampled interviewees who had been participants in research and development activities in Uganda and Ethiopia were only included in calculating total crop coverage and marketing figures which were considered independent of participation.

Knowledge and Information Survey

Second, a survey was conducted among potato producers in Kenya, Uganda and Ethiopia to assess the relative importance of different sources for information on potato farming practices and marketing.

In Kenya, Bomet and Nyandarua were selected as sample districts. Nyandarua represents potato farming for the wholesale ware potato market, whereas Bomet is important for the production of potatoes for crisp processing. In Bomet district, farm households were randomly selected equally among its six divisions. Interviews were conducted in May 2004. In Nyandarua, farmers were selected randomly in Kipipiri and North Kinangop divisions, which are considered to be representative of potato farming in Nyandarua district. Within the divisions, locations, sublocations and villages were randomly selected. Within the villages, households were selected through a random transect walk, selecting each fifth household. Interviews were conducted in October 2004.

In Uganda, Kabale district, which produces the highest bulk of potatoes (Low 1997) was selected as a sample district. Ten out of 19 subcounties in this district were selected randomly for the survey. Within each parish in the selected subcounties, a village was sampled. Farm households were selected randomly from a list of households provided by a village elder. The survey was implemented in September 2005.

In Ethiopia, Jeldu, Dendi and Wolemera districts were selected in the West Shewa zone, Degem district in the North Shewa zone and Alemaya district in the East Shewa zone. These districts were chosen because of the importance of potato in the farming system, their differences in potato farming practices, and because they are intervention areas for potato agro-enterprise development by various development organizations. Within these districts peasant associations (the lowest administrative unit) were randomly selected and within this farm households were picked at random from a list of all farmer families provided by the local office of the Ministry of Agriculture. The interviews were conducted in June and July 2004.

In Kenya, Uganda and Ethiopia, 97, 211 and 646 farm households were interviewed, respectively. The total target of interviewed farmers was adapted to the resources available in each country. Farmers were interviewed using a questionnaire that had been developed by the researchers from the three countries, followed by appropriate adaptation for each country.

Stakeholder Meetings To Assess a Potato-Related Innovation System

Stakeholder workshops were organized to identify constraints and opportunities in the potato sector in Kenya, Uganda and Ethiopia. An assessment of the system was made from an innovation system perspective, focusing primarily on the interrelations between the stakeholders and their respective roles in knowledge development and information exchange. In Kenya, two single-day stakeholder workshops were conducted in both Bomet (11 June 2004 and 13 January 2005) and Nyandarua (19 October 2004 and 16 November 2005) districts. In Uganda, a single-day workshop with potato stakeholders from Kabale district was organized on 9 March 2005. In Ethiopia, the meeting consisted of a single event from 21 to 23 July 2004, with representatives of potato sector stakeholders from the Alemaya, Galessa, Jeldu and Degem districts. Stakeholder categories present at the meeting varied for each country as a result of different responses to invitations to attend.

Workshop participants were grouped together according to stakeholder category, for example ware potato farmers, seed potato farmers, public extension staff,

representatives of non-governmental organizations intervening in rural development, processors, transporters and agro-input suppliers. Stakeholder categories present in the meeting varied per country as a result of different responses to invitations to attend. All groups analysed their own role and the role of other stakeholders in the potato chain and an actor linkage matrix of all interactions was constructed, adapted from a method described by Biggs and Matsaert (1999). First, every stakeholder group identified its interactions with other stakeholder groups in the potato chain. Consecutively the constraints in these interactions were identified. The actor linkage matrix was constructed by the workshop facilitators (Fig. 1) and the opinions of the different stakeholder groups about each other were presented in a plenary for discussion.

In Kenya, in the second workshop in both Bomet and Nyandarua, the problems identified in the first workshop were prioritized through a ranking exercise. Next, solutions to the most important constraints were discussed in mixed groups consisting of different stakeholder categories. The group results were reported back to the plenary for further elaboration.

Potato Production System Characterization

Trends in Potato Production and Productivity

Potato production is projected to grow by 2.7% a year globally until 2020 (Scott et al. 2000), a growth that exceeds growth of all other major food crops. For sub-Saharan Africa the same authors project an annual growth in demand of 3.1%. Figure 2 shows the growth of the estimated area under potato in Kenya, Uganda and Ethiopia from 1996 until 2006. A steady increase in area over time can be observed: the average increase is 4.3% per year for Kenya and 7.0% per year for Uganda. For

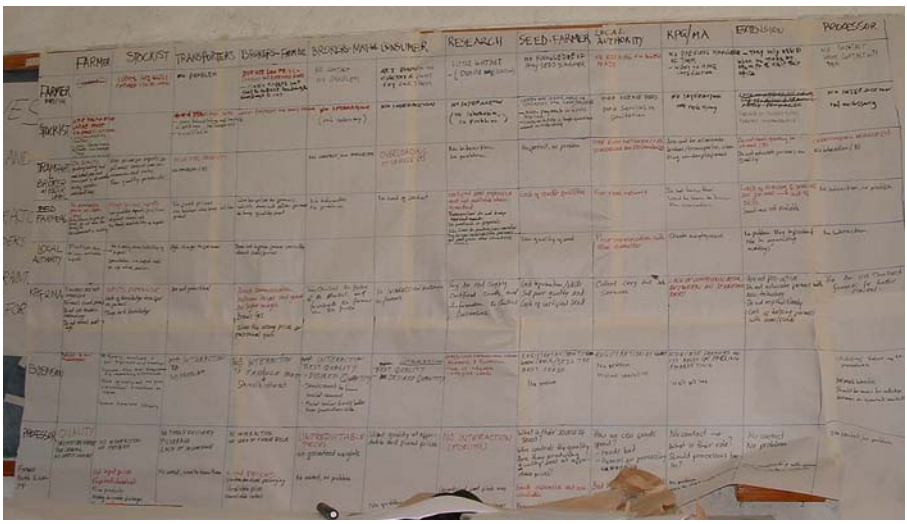

Fig. 1 Actor linkage matrix in Nyandarua, Kenya, 2004

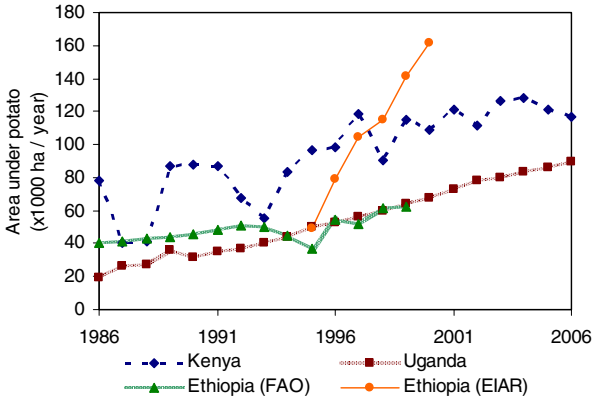

Fig. 2 Area under potato in Kenya, Uganda and Ethiopia from 1986–2006. Source: Faostat, 10–2007; EIAR 2007

Ethiopia, the FAO reports a modest growth in area of 2.6% per year, which contrasts sharply with data gathered by the potato research station of the Ethiopian Institute of Agricultural Research for the years 1995–2000 (Ethiopian Institute of Agricultural Research, unpublished data), which show an explosive growth in area of 22% per year (Fig. 2).

For the same period during which the area under production increased rapidly, limited change in productivity per unit area can be observed (Fig. 3). This clearly shows that the growing demand is met by area increase, rather than by yield increase.

Potato productivity estimates in the surveys indicate yields in Kenya of 9.1 Mg ha^{-1} (Table 1), whereas in Uganda farmers estimated average yields of 5.8 Mg ha^{-1}, which is well below the yields estimates provided by the FAO (Fig. 3). In Ethiopia, farmers estimated yielding an average of 7.9 Mg ha^{-1}, which is in line with the FAO data.

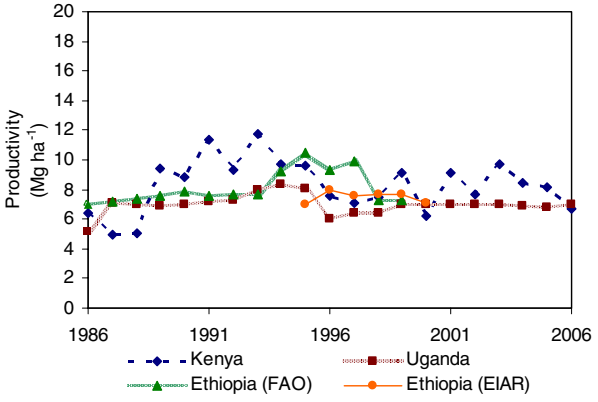

Fig. 3 Productivity of potato (Mg ha^{-1}) in Kenya, Uganda and Ethiopia from 1986–2006. Source: Faostat, 10-2007; EIAR 2007

Table 1 Average potato productivity as estimated by farmers in Kenya, Uganda and Ethiopia (Mg ha^{-1})

	Kenya	Uganda	Ethiopia
Average production	9.1	5.8	7.9
Median	7.7	4.2	6.0
Standard Error of Mean	0.35	0.43	0.44
n	249	128	177

Source: potato practices and technology survey

Potato Production Seasons

Most potato farming occurs under rain-fed conditions. Consequently, the major cropping seasons follow the rainy seasons (Fig. 4).

In Kenya, two seasons with ample rainfall for potato cultivation could be identified (Fig. 4). The length of the seasons depended on the region. Limited off-season production occurred in areas higher than 2,000 m above sea level, on slopes receiving intermittent rainfall and mist, which, combined with residual moisture, could support a potato crop in most years. Irrigated out-of-season potato farming was virtually limited to Abo West division in Meru Central district, on the slopes of Mt. Kenya, where farmers use small sprinklers which are connected to upslope streams, and operate using the force of gravity. Most potato farmers in Abo West timed potato production in such a manner that they could harvest potatoes in-between the supply peaks of the rain-fed crop.

In Uganda, two main production seasons were identified, coinciding with the short and long rainy seasons. However, in Kabale district, a third cropping season can be recognized after the short rainy season (Fig. 4). During this time, potato is planted in valley bottoms or drained wetlands. The crop is supported by the residual moisture available in the rich organic soil or drainage water coming from the surrounding hills.

In Ethiopia in most of the potato farming zones, two rainy seasons can be identified, the main (Meher) season and a short rainy season (Belg). Rainfed potato farming during the Belg season is practiced at high altitude, where evapotranspiration is low and rainfall higher than average in the country. However, in most areas the Belg season is short and unreliable and supplementary irrigation is imperative.

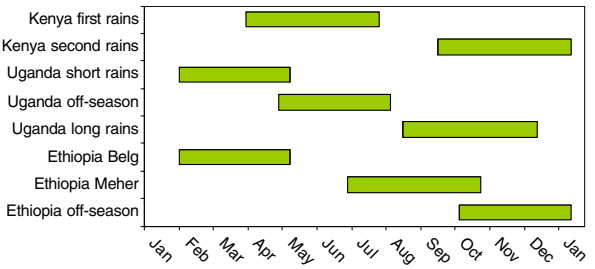

Fig. 4 Main potato growing seasons in Kenya, Uganda and Ethiopia

Considerable differences in rainfall patterns occur between and even within potato growing zones in Ethiopia, which means there are many exceptions to the main potato growing seasons presented in Fig. 4.

Importance of the Potato Crop in the Farming System

In Kenya, the majority of sampled farmers cultivated potato twice a year, during the main rainy seasons. Potato farmers dedicated more than a third of their arable land to potato in both districts during both seasons (Table 2). During the first rainy season of 2005, potato covered 30% of the total cropped area in the sample districts (Fig. 5).

In Uganda, the majority of sampled farmers grew potato twice a year, dedicating 24–32% of their arable land to potato depending on the season and district (Table 2). During the short rainy season of 2005, 24 and 23% of all arable land in Kabale and Kisoro, respectively, was cropped to potato (Fig. 5).

In Ethiopia, the main potato growing season depended on the zone (Table 2). In West Shewa, the main production season was during the Belg season, in North Shewa it was during the Meher season, and in Awi zone more farmers grew potato during the Belg and off-season than during the Meher season. Of all crops grown during the Meher season of 2006, potato occupied 7, 8 and 13% of all cropped land in North Shewa, Awi and West Shewa zones, respectively (Fig. 5).

Use of Agricultural Inputs

Fertilizer Use

Farmyard manure can supplement inorganic fertilizer to maintain soil fertility. It was, however, only widely used in Kenya, where 45% of the farmers indicated having used manure on their last potato crop, compared with 18 and 26% of potato farmers in Uganda and Ethiopia, respectively (Table 3). The average amount of farmyard manure applied in Kenya by those farmers using it contained 48 and 13 kg of nitrogen and phosphorus, respectively, if one uses the farmyard manure composition figures presented by Lekasi et al. (2003).

Table 3 shows large differences amongst the countries in utilization of fertilizer in potato farming. In Kenya, the vast majority of farmers used mineral fertilizers in potato farming, and in substantial quantities, although the rates used were on average less than half of the recommended amounts of nitrogen and phosphorous of 90 and 230 kg ha^{-1} in the form of diammonium phosphate (18:46) (source: KARI-Tigoni). In Uganda, fertilizer use on potatoes was virtually absent, which shows there had been no change in practices since this was last assessed by Low (1997). In Ethiopia, more than half of the potato farmers indicated having used fertilizers on their last potato crop, however in lower quantities than Kenyan farmers.

Seed Potato Source and Renewal

Low seed potato quality is a major constraint of potato farmers in Kenya, Uganda and Ethiopia (Gildemacher et al. 2009b). The seed potato system in the three

Table 2 Percentage of farms cultivating potato, average size of potato fields and the proportion of arable land devoted to potato on farms growing potato during different seasons in Meru Central and Nyandarua districts of Kenya (2004–2005), Kabale and Kisoro districts of Uganda (2004–2005) and the West Shewa, North Shewa and Awi zones of Ethiopia (2005–2006)

	Farms growing potatoes (%)	Potato fields (ha/farm)	Fraction potatoes (% of farm)
Kenya			
Meru Central (n=100)			
Season 1 (April–July)	77	0.32	42
Season 2 (Oct–Jan)	95	0.34	38
Off-season (Jul–Oct)	9	nd	nd
Nyandarua (n=151)			
Season 1 (April–July)	93	0.40	35
Season 2 (Oct–Jan)	99	0.47	37
Off-season (Jul–Oct)	0		
Uganda			
Kabale (n=169)			
Season 1 (April–July)	91	0.27	25
Season 2 (Oct–Jan)	72	0.28	26
Off-season (Jul–Oct)	28	nd	nd
Kisoro (n=61)			
Season 1 (April–July)	80	0.23	28
Season 2 (Oct–Jan)	92	0.25	32
Off-season (Jul–Oct)	8	nd	nd
Ethiopia			
West Shewa (n=138)			
Belg season (Feb–May)	83	0.27	20
Meher season (Jun–Oct)	53	0.43	34
Off-season (Oct–Jan)	7	0.17	13
North Shewa (n=104)			
Belg season (Feb–May)	9	0.14	8
Meher season (Jun–Oct)	86	0.18	9
Off-season (Oct–Jan)	17	0.16	6
Awi (n=94)			
Belg season (Feb–May)	84	0.24	29
Meher season (Jun–Oct)	40	0.21	21
Off-season (Oct–Jan)	65	0.20	23

Source: potato practices and technology survey

nd=no data

countries is characterized by limited availability and use of commercially traded high-quality seed potato.

Assessment of seed potato renewal revealed that in Kenya 41%, in Uganda 26% and in Ethiopia 44% of the farmers periodically renewed their seed stock. On average, those

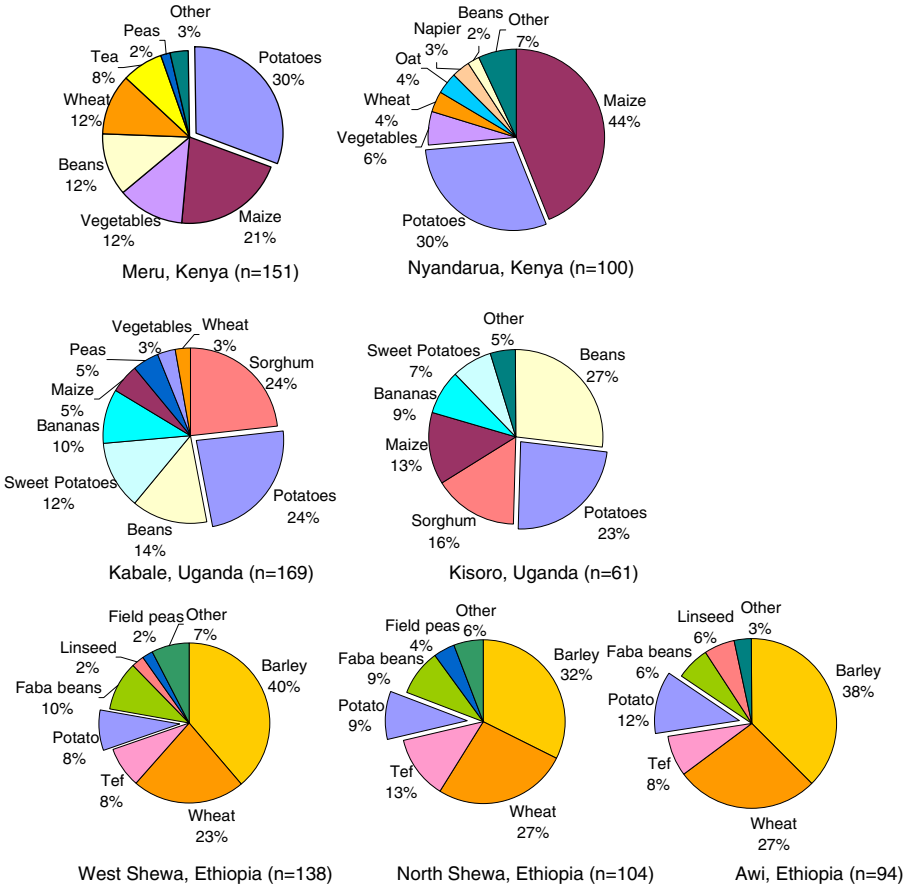

Fig. 5 Total proportions of arable land cropped to different crops during the first rainy season in Kenya and Uganda in 2005 and the Meher season in Ethiopia in 2006. Source: potato practices and technology survey

farmers who did renew their seed did so after six seasons in Kenya, seven seasons in Uganda and three seasons in Ethiopia. The most important source of seed potato in Kenya was neighbours, while in Uganda and Ethiopia the village market was the dominant source. Specialized seed growers were a source of seed in only 2% of the cases in Kenya, compared with 10% in Uganda and 16% in Ethiopia (Table 4).

Potato Marketing System Characterization

Home Consumption Versus Marketing

The study also confirmed that potato is a dual-purpose crop in the three countries studied. It serves both the household staple food requirement and as a source of cash income. On average, potato farmers in Kenya produced more potato tubers than their counterparts in Uganda and Ethiopia. Farmers in Kenya marketed over 80% of their

Table 3 Percentage of potato farmers in Kenya, Uganda and Ethiopia using farmyard manure and mineral fertilizer and the average amounts applied by these users

	Farmyard manure (FYM)			Fertilizer				
	Farmers using FYM (%)	FYM applied (kg/ha)	s.e.	Farmers using fertilizer (%)	N applied (kg/ha)	s.e.	P applied (kg/ha)	s.e.
Kenya (n=251)	45.0	4327	512	87.8	43.3	2.0	101.4	4.7
Uganda (n=141)	17.7	2207	606	4.7	37.6	18.9	46.9	45.1
Ethiopia (n=287)	26.1	3006	317	57.2	30.6	2.5	33.4	2.3

Outliers in farmer estimates of applied amounts were removed by skimming the top 5% estimates

Source: potato practices and technology survey

harvest after satisfying their home consumption and seed potato needs, while in Uganda 71% of the produce was sold, compared with 61% in Ethiopia (Table 5).

Kenyan farmers sold a smaller proportion as seed potato, but tended to keep more seed potatoes for their own production than the farmers in Uganda and Ethiopia. The survey shows that farmers in Kenya tended to plant bigger seed potatoes than their peers in Uganda and Ethiopia. Furthermore, the combination of a higher productivity and a larger average area under the crop in Kenya compared with Uganda and Ethiopia resulted in a larger proportion of surplus potatoes for the market after satisfying the home needs for seed and consumption potatoes (Table 5).

Potato Marketing Channels

In Kenya, the bulk of potato (87%) was sold to traders direct from the field, mostly assisted by field brokers (Table 6). The field brokers scout for potato fields that are

Table 4 Seed potato renewal frequencies and sources of seed in Kenya, Uganda and Ethiopia

	Kenya	Uganda	Ethiopia
Seed renewal frequency			
Farmers renewing seed stock (%)	41	26	44
Average renewal period (seasons)	6	7	3
n	250	141	186
Source of seed last renewal (%)			
Neighbour	94	34	14
Market	5	56	69
Specialized seed grower	2	10	16
n	311	157	301

Source: potato practices and technology survey

Table 5 Marketed potato yield versus home consumption in Kenya, Uganda and Ethiopia

	Kenya (n=96)		Uganda (n=154)		Ethiopia (n=419)	
	Weight (kg) per household per season	Percent	Weight (kg) per household per season	Percent	Weight (kg) per household per season	Percent
Ware sold	2,899	77	753	61	528	48
Seed sold	165	4	112	9	146	13
Ware home	327	9	191	16	300	27
Seed home	352	9	170	14	126	11
Total	3,743		1,226		1,107	
Total market	3,065	82	865	71	673	61
Total home	679	18	361	29	434	39

Source: potato practices and technology survey

ready to be harvested and negotiate deals ahead of the arrival of a transporter. In Uganda, roughly two thirds of the ware potatoes were traded directly from the field, while 25% of the ware potato produce was sold through village markets. In Ethiopia, most ware potato farmers took their produce piecemeal to village markets, often on horseback or carried by hand, where it was sold to wholesalers.

The data indicated that Kenya and Uganda had a better developed marketing system, where farmers can sell directly from their fields to brokers. This reduces the need for on-farm ware potato storage, minimizes the efforts farmers have to make to sell their produce and maximizes the sum received at once, thus facilitating meaningful investment of their revenue. However, the potato farmers in the stakeholder workshops in Kenya indicated that this marketing system is far from perfect. It gives field-level brokers a leverage to offer low farm-gate prices to increase their own profit margin at the cost of farmer efforts. However, the village brokers play a significant role as a link between the urban-based potato traders and the potato farmers.

In the three countries studied, farmers traded their produce predominantly as individuals. Only in Ethiopia very few farmers sold their potato produce through a farmer cooperative or non-governmental organization (Table 6).

Table 6 Marketing outlets used by potato producers in Kenya, Uganda and Ethiopia

	Potato marketing channel (%)		
	Farmgate to trader / broker	Village market	Other[a]
Kenya (n=105)	87	8	6
Uganda (n=175)	68	25	8
Ethiopia (n=435)	4	88	8

Source: knowledge and information survey

[a] Includes roadside sale, farm gate retailing, farmer cooperative and NGO

Potato Production Economics

Profitability of Potato Production

In Meru Central (Kenya), farmers invested more in their potato production than did farmers in other sampled areas (Table 7). A relatively high average yield and fairly high prices resulted in a positive net margin, and a high return on family labour. In

Table 7 Average production costs and revenues of potato production in major potato production areas of Kenya, Uganda and Ethiopia, 2005–2006[a]

	Kenya (n=251)		Uganda (n=144)		Ethiopia (n=220)		
	Meru Central	Nyandarua	Kabale	Kisoro	West Shewa	North Shewa	Awi
Cash investments							
Cost fertilizer (US$/ha)	118.40	79.49	1.81	7.27	21.12	4.12	5.84
Cost fungicides (US$/ha)	33.21	16.22	25.31	26.34	38.57	2.85	0.00
Hired labour used (US$/ha)	104.34	103.32	45.61	50.82	120.38	110.39	85.51
In kind investments							
Cost manure (US$/ha)	30.67	5.86	0.83	1.68	3.23	2.42	1.99
Cost seed (US$/ha)[b]	123.37	72.94	96.56	72.37	65.84	88.72	144.10
Family labour investments							
Family labour used (days/ha)	97.83	210.57	227.81	211.59	117.00	125.99	149.16
Family labour (opp. cost; US$/ha)[c]	100.38	197.04	107.87	85.63	116.46	149.87	156.27
Revenues							
Yield (Mg ha^{-1})	8.83	9.21	5.25	6.83	7.69	12.33	5.14
Price (US$/Mg)	80.16	45.10	88.09	72.06	62.44	79.12	91.22
Gross margin (US$/ha)	707.85	415.34	462.45	492.14	480.09	975.73	468.89
Net margin (opp. cost; US$/ha)	197.48	−59.52	184.45	248.04	114.50	617.36	75.19
Net margin (no opp. cost; US$/ha)[d]	297.86	137.51	292.33	333.67	230.96	767.23	231.46
Return on family labour (US$/day)[e]	4.13	0.97	2.08	2.99	1.97	6.09	1.55
Return on cash investment (US$/US$)[e]	1.77	1.09	5.36	4.83	1.67	7.31	4.13

[a] Figures presented are calculated from the average of all valid farmer estimates. Farmers have estimated costs and revenues per plot per season, which was then weighed for area over seasons, cultivars and plots

[b] Cost of seed is put at the average price of ware potato because of widespread use of farm-saved seed

[c] Opportunity cost of labour is put equal to average estimated cost of hired labour

[d] No opportunity costs are calculated for family labour

[e] Net margin divided by days of family labour

[e] (Gross margin minus cash investments) / cash investments; only fertilizer, fungicides and hired labour are considered cash investments

Source: potato practices and technology survey

Nyandarua, yields were comparable to those in Meru Central, but the prices farmers received for their produce were very low, and in spite of lower cash investments their net margin was negative. The low investments in fertilizer, fungicides and hired labour in Nyandarua compared with Meru, and the use of more family labour are an understandable reaction to the low prices. In this manner potato farmers do get a positive return on their cash investment, providing them with some cash income as well as food from their potato production. Return on their labour, however, is lower than the opportunity cost.

Farmers in both Kabale and Kisoro districts in Uganda obtained net margins comparable to those of farmers in Meru Central in Kenya (Table 7) although mean yields were lower in Uganda than in Kenya. In Uganda, cash investments in potato production were lower than in Kenya as farmers hardly used fertilizer, labour was cheaper in Uganda and farmers used more family labour than in Kenya.

In Ethiopia, specifically farmers in North Shewa were making good profits compared with all other sampled districts. This is the combined result of much higher yields compared with those in West Shewa and Awi zones, low investments in inputs and a relatively good price. In West Shewa both yields and prices were lower, while in Awi zone prices were good, but yields very low.

Return on Cash Investment

The return on cash investment was more than 100% in all sampled districts (Table 7). It can be concluded that the smallholder potato farmers are risk-averse in terms of their cash investment. An economic strategy can be observed in which growers minimize the risk of cash losses as a result of their potato production. The producers are reluctant to invest their scarce cash resources in seed potatoes, fertilizer and fungicides, even though this could increase their profits and, at least partially, they rely on their own labour and seed potatoes, and minimize the use of fertilizer in their production system. The risk-adverse decision making with regard to cash investments is an economically sensible response to insecurities regarding potato diseases, drought and potato prices.

Return on Family Labour

In all sampled areas, except Nyandarua district in Kenya, the return on family labour in terms of cash income was higher than the opportunity cost for the labour. This confirms that potato production can effectively contribute to the cash requirement of smallholder households and provides profitable employment to smallholder farmers.

The negative net margin in Nyandarua does not mean that farmers are making irrational economic decisions by farming potatoes. The net margin was derived after giving a value to their family labour at the average rate of hired farm labour in their district. Furthermore, a cost was attached to their seed potato. In the first place, the rural economy is far from perfect, and a productive alternative use of the family labour may not be possible. Secondly, farmers use their own recycled seed potatoes as seed, which have no cost to the farmer, and are not easily marketable. Thirdly, farmers in Nyandarua did have a positive return on their cash investment, thus providing the household with scarce cash resources. Lastly, their potato crop

provides the household with food which would otherwise have required cash to purchase it.

Identification of Technical Yield Reducing Factors and Innovation Priorities

Improving Productivity

Over the last 20 years potato production increase in East Africa has been driven by area expansion as previously observed. However, further potato production increase through area expansion will become increasingly difficult. Further area expansion in the highlands could fuel encroachment on the limited remaining highland forests in eastern Africa. A high proportion of potato production within the rotation is not sustainable from the point of view of soil-borne pest and disease management and soil structure and fertility management (Struik and Wiersema 1999). Especially in Kenya and Uganda the proportion of land cropped to potato is already high (Fig. 5). In the North Shewa zone in Ethiopia, there appears to be more opportunity for additional potato production within the rotation (Fig. 5, Table 2).

The most feasible manner in which the growing demand for potatoes can be satisfied is through increased productivity. Occasionally, substantially higher yields per unit area than presented in Fig. 3 and Table 1 were obtained by farmers under the same rain-fed production circumstances as neighbouring farmers. Gildemacher et al. (2007a) reported 12 Mg ha^{-1} in Kenya in farmer-managed trials using normal farmer practices. Average yields from a large number of trials in the region were reported at 20 Mg ha^{-1} (Gildemacher et al. 2007b). The average yields of the top 10% in the potato practices and technology survey are 17.4, 12.0 and 17.0 Mg of potatoes per hectare in Kenya, Uganda and Ethiopia, respectively, which is twice as much as the national averages presented in Table 1.

This means that there is a potential to increase potato yields substantially compared with the current yield levels, especially considering the profitability of potato production demonstrated in Table 7. On the basis of the outcomes of the stakeholder workshops, combined with the quantitative data from the two surveys, four key technical areas that need to be addressed to increase productivity have been identified by the authors:

1. Seed potato quality management
2. Management of bacterial wilt (caused by *Ralstonia solanacearum*)
3. Management of late blight (caused by *Phytophthora infestans*)
4. Soil fertility management

These areas will be discussed next.

Seed Potato Quality Management

One of the main technical issues raised by farmers during the stakeholder workshops was the limited availability and use of quality seed potatoes (Gildemacher et al. 2007a). The smallholder potato producers were giving both scientists and extension staff the challenge of ensuring the supply of high-quality seed potatoes. Ware potato

farmers, seed multipliers and scientists agreed that improving the quality of seed potatoes used by the smallholder potato producers was an important requirement for the increase of productivity.

Considering the short crop rotations that farmers practise, seed potato quality is an important factor in improving the sustainability of production. The management of soil-borne pests and diseases depends on the combination of ample crop rotation and the use of quality disease-free seed potatoes.

Without periodic renewal of the seed potato stock, tuber-borne diseases build up in the seed stock that farmers use. Especially virus diseases are suspected to cause widespread and large yield reductions. In an extensive training programme on virus diseases, researchers in Kenya (Gildemacher et al. 2007a) have learned that the majority of ware potato producers did not recognize virus infection as a disease. The majority of farmers perceived virus symptoms as a normal characteristic of a potato crop. Virus diseases were not mentioned by farmers as one of the important diseases that hamper potato production, but farmers in the stakeholder workshops indicated they lack a reliable source of timely available and affordable high-quality seed potatoes. This indicates that farmers to some extent are aware of the importance of high-quality seed potato to obtain high yield. The prevalence of potato viruses became very clear as a result of a survey sampling seed potatoes sold at rural markets in Kenya. Only 0.4% of all sampled tubers were free of the main four potato viruses (Gildemacher et al. 2007b).

The major challenge is that in the current potato system seed potatoes are not routinely bought by farmers as an input into their farming system. Shifting towards a mechanism where potato producers routinely renew their seeds to keep the yield potential high means a major shift in the potato system in the three countries. Before technological or system innovations to improve the quality of seed potatoes used by smallholder farmers are offered, a more thorough study of the functioning of the current seed potato system is required, which is reported separately (Gildemacher et al. 2009b).

Bacterial Wilt Control

Bacterial wilt (*Ralsonia solanacearum*) forms another major threat to intensive potato production in the East African highlands. Surveys in Kenya showed that 59% of the sampled potato plots in the upper highlands and up to 86% of potato fields below 2,000 m above sea level were infested with bacterial wilt (Wakahiu et al. 2007). Farmers in both Kenya and Uganda mentioned bacterial wilt most frequently when asked about pest and disease problems in potato production during the survey (Table 8). Earlier, Turkensteen (1987) identified bacterial wilt and late blight as the two most important pathogens in African potato growing systems. In the stakeholder workshops in Kenya and Uganda, bacterial wilt and its management was a hotly debated topic.

The bacterial wilt problems are expected to increase as a result of shortening rotation. The disease survives in the soil for several seasons, and one essential component of bacterial wilt management is denying the bacteria a host by not growing potatoes or any other host crop for several seasons, combined with a strict removal of volunteer potato plants (Lemaga et al. 2005).

Table 8 Potato disease problems prioritized by farmers in Kenya and Uganda, 2004–2005

	Kenya (n=99)	Uganda (n=155)
Late blight (*Phytophtora infestans*)	49	119
Bacterial wilt (*Ralstonia solanacearum*)	71	132
Other	1	2

Source: knowledge and information survey

The management of bacterial wilt is further complicated by the lack of reliable seed sources and the heavy reliance on farm saved seed potatoes as planting material, which results in frequent reinfection of fields. The bacteria survive in non-symptomatic tubers that are stored for future planting, and the disease spreads once these tubers are planted. Bacterial wilt control as a point of intervention to improve potato productivity will have to include a seed potato quality management component, and is thus strongly related to the topic above.

Late Blight Control

Late blight (*Phytophthora infestans*) is a major potato disease that can result in the total destruction of the crop. Average yield losses were 20% over a large number of on-station trials in six countries in eastern and central Africa on potato cultivars with levels of host resistance to the pathogen (Gildemacher et al. 2007b). In both Kenya and Uganda, late blight was mentioned most frequently after bacterial wilt as the major disease constraint of potato (Table 8). This reconfirms the findings of Nyankanga et al. (2004), Turkensteen (1987) and Low (1997).

Late blight is the major reason for the use of pesticides on potatoes in Kenya (Nyankanga et al. 2004), Uganda (Low 1997) and Ethiopia. Even if late blight is kept under control by farmers through the use of fungicides, there are both economic and ecological consequences of the pathogen. These may not be considered by farmers when ranking potato diseases. Although late blight was considered second in importance to bacterial wilt by farmers in the survey (Table 8), it may well present an even more important yield- and revenue-reducing factor. This is confirmed by its ranking as the priority crop management need by potato scientists from Africa (Fuglie 2007).

Soil Fertility Management

There were large differences in the soil fertility management practices among the three countries. In Kenya, substantial amounts of nutrients were added to the soil in the form of farmyard manure and mineral fertilizer, mainly diammonium phosphate (18:46), while in Ethiopia the use of mineral fertilizers was much less important. In Uganda, very few farmers used any soil supplements, either organic or mineral, in potato production (Table 3).

Potato yields in Kenya were higher than in the other two countries (Table 1). This could well be the result of better soil fertility management than in Ethiopia and

Uganda. The only exception was in North Shewa, Ethiopia, where limited quantities of fertilizers were used, but yields were the highest of all three countries. This may be related to a more extensive farming system, with more rotation opportunities and a longer fallow period owing to larger farm sizes.

Soil fertility management did not feature prominently as a technical constraint in the stakeholder workshops. Farmers considered high fertilizer prices as a constraint, especially in Kenya. In spite of this lack of concern shown by farmers regarding soil fertility management, the potato yield levels indicate that they are far below their actual potential and that attention is needed in this field in the three countries to increase productivity in a sustainable manner. This opinion is shared with the scientists involved in the priority setting done by Fuglie (2007), who rated this topic as the priority in sub-Saharan Africa.

A specific area of interest is the study of how to optimize the use of limited amounts of fertilizer. Even in Kenya the average amount of mineral fertilizer used by farmers is still less than half the rate recommended. Optimizing the manner in which the amounts of fertilizer that potato farmers in sub-Saharan Africa can afford are best combined with the usually also inadequate organic sources of nutrients available to them is an important area for further research (Vanlauwe and Giller 2006).

Potato Innovation System

The four areas that were identified as technical intervention points for improving potato productivity will help in targeting research and development efforts for the potato sector in the region. Effective problem solving, however, requires more than problem identification. The success of research and development efforts depends largely on the context in which they are initiated. According to the stakeholders in the workshops, two non-technical elements need specific consideration, and these were the marketing system and the knowledge and information system. Both can be seen as 'functions' of the potato innovation system. In this section, the functioning of the potato innovation system is analysed and the question is answered how the potato-related innovation system can support improvement of the potato sector in general, and specifically ensure an environment in which the technical innovation priorities identified above can be tackled.

Potato Marketing

Improving productivity alone will not always result in a dramatic improvement of profitability (Table 7). With the exception of Meru Central in Kenya, most farmers have a production strategy that reduces risk through minimizing cash investment in the potato production, thus fulfilling their dual objective of cash income and household food security. When considering the current profit margins, this may well be an optimal production strategy. Under the low price expectations in Nyandarua, a farmer would be reluctant to invest cash to improve his potato production. Prices in West Shewa in Ethiopia are also fairly low compared with those in the other sample regions, even though it is in the relative vicinity of Addis Ababa.

During the stakeholder workshops in the three countries, topics related to potato marketing featured prominently (Gildemacher et al. 2009a), confirming that potato marketing is a serious constraint for farmers and a major driver in decision making. Any attempt to increase potato productivity will require some form of investment by the potato farmers. It may require cash investments in the form of buying higher-quality seed potatoes, fertilizers or other agrochemicals. It could also require investments in time in the form of integrated management of bacterial wilt or improved on-farm seed potato selection. Farmers will be reluctant to invest these resources required for adopting innovative technology that could improve their productivity when there is no clear market incentive to do so. Certainly for Nyandarua in Kenya, but basically for all districts, technological innovation by farmers would be helped by reducing marketing insecurities. As such, parallel technical and marketing interventions would increase the probability of success.

Knowledge Development and Information Exchange

Knowledge development and information sharing are essential for the achievement of potato system improvement through technological innovation, and these are key functions of the innovation system. In the stakeholder workshops in the three countries, the interaction between actors managing potato information was found inadequate and was identified as a key area for improvement.

Douthwaite (2002) looked at innovation from the perspective of fostering technological change, and proposed the 'learning selection approach', an evolutionary approach towards technological development in which bright ideas are tested and adapted until they are 'fit' enough to become useful. The technological innovations 'surviving' this process will have become adapted to the environment in which they have been developed. As such, imperfections in the existing system are 'fixed' with adapted technology.

Other authors put more emphasis on the co-evolution of the technology and its environment, under the assumption that both are dynamic and will require more or less adaptation to facilitate positive change (Biggs and Smith 1998; Leeuwis 2000; Campilan 2002; Elzen and Wieczorek 2005; Geels 2005). Depending on the actual technology, innovation requires to a larger or lesser extent changes in the interrelations and formal and informal rules of conduct between stakeholders. Successful innovation thus depends on moulding and adaptation of both the technology and the environment in which it operates.

The stimulation of rural development, or in other words the 'moulding and adaptation process', is best viewed from a negotiation and learning perspective, rather than as a well-structured planning and decision making process (Leeuwis 2000). The processes of network building, social learning and negotiation deserve particular support as they can catalyse system innovation (Leeuwis 2004). Similarly, Campilan (2002) concluded from empirical cases in Nepal that a social learning process is required for successful potato integrated disease management. In this social learning process, stakeholders jointly define the problem situation, design technical interventions, set up the corresponding social arrangements and learn to manage the links between these social and technical components.

Whether one focuses primarily on the evolution of technology, or on the co-evolution of technology and its environment, an understanding of the current dynamics of the system is required. It is essential to understand the existing potato system and its interactions with 'niche-innovation' (new technology) and the wider environment or 'sociotechnical landscape' (Geels and Schot 2007). Innovation through a negotiation and learning process can only be initiated after it has been assessed whether the vital preconditions are met, which include institutional manoeuvring space, a sense of urgency of change among stakeholders and a basic level of trust between stakeholders (Leeuwis 2004).

Engel (1997) proposed analysing systems from a stakeholder interaction perspective, with particular focus on the knowledge and information system. Following Engel (1997), the 'AKIS-potato' could be defined as a group of individuals, public organizations (governmental and non-governmental) and the private sector that exchange information and knowledge related to potato management, processing and trade. Understanding this system, its components and the way in which they interact is the essential first step for a more efficient innovation system (Lundvall et al. 2002; Hall et al. 2003).

Quantification of Information Sources of Potato Producers

Through the knowledge and information survey, potato farmers were asked to indicate the initial sources of information on potato production technologies and marketing. Tables 9, 10 and 11 show from where the sampled potato producers indicated they obtained information on different aspects of potato production and marketing in Kenya, Uganda and Ethiopia respectively.

Information on crop husbandry, seed potato selection and postharvest handling, which entail most of the routine farming operations, was considered by farmers to be developed through their own experience. Apparently many farmers do not regard this knowledge as derived from an identifiable source of information, but rather evolved through experience of the user. A considerable proportion of farmers in Uganda and Kenya indicated the public agricultural extension service, non-governmental organizations in the field of agricultural development (hereafter called NGOs) or events organized by these actors as a principal source of information on practices related to seed potato selection, soil fertility management, general crop husbandry and postharvest handling. In comparison, in Ethiopia the combined public and non-governmental extension actors play a more marginal role as a source of information on these farming practices.

The majority of farmers indicated having obtained the first information about the potato cultivars that they grow from fellow farmers within the local community. Family members were a second source of information on potato cultivar. Extension actors and NGOs only play an important role regarding information on cultivars in Ethiopia, while the research organizations were mentioned sporadically as a source of information on potato cultivars in each country. Potato traders seemed not to play any role in providing information on new potato cultivars.

For information on crop protection, farmers relied less on their own experience and the role of extension actors was more important here than in other categories. Also research was mentioned more frequently as a source of

Table 9 Summary of farmer information sources in production and marketing of potato in Nyandarua and Bomet districts in Kenya, 2004

Farming practice	Most important source of information (%)								
	Own experience	Family member	Farmer own community	Extension / NGO	Research	Publication / media	Private sector	Others	n[b]
Potato varieties	12.6 **II**	5.0	73.4 **I**	6.0 **III**	1.5	1.0	0.0	0.5	199
Seed potato selection	48.5 **I**	6.8	22.0 **II**	21.1 **III**	0.0	1.7	0.0	0.0	355
Soil fertility management	58.9 **I**	6.9	13.1 **III**	18.3 **II**	0.0	1.7	0.6	0.6	175
General crop husbandry	54.9 **I**	11.7	13.1 **III**	19.4 **II**	0.2	0.2	0.4	0.2	557
Post harvest handling	48.7 **I**	14.8	19.6 **II**	16.9 **III**	0.0	0.0	0.0	0.0	189
Marketing	41.4 **I**	15.2 **III**	23.2 **II**	11.1	0.0	7.1	2.0	0.0	99
Crop protection	29.0 **I**	7.0	27.0 **II**	20.0 **III**	2.0	2.0	13.0	0.0	100

[a] Bold roman numbers highlight the three most mentioned information sources for each farming practice

[b] Within each farming practice category, different topics were included (not presented). The farmers were asked to only mention the single, most important source of information for these topics. n refers to the total number of valid responses on the different topics within a farming practice category. Total number of respondents=97

Source: knowledge and information survey

Table 10 Summary of farmer information sources for production and marketing of potato in Kabale district, Uganda, 2005

Farming practice[a]	Most important source of information (%)							
	Own experience	Family member	Farmer own community	Extension / NGO	Research	Potato traders	Others	n[b]
Potato varieties	15.9 **II**	11.3 **III**	69.2 **I**	0.0	2.6	0.0	1.0	195
Seed potato selection	46.8 **I**	0.0	24.7 **III**	25.9 **II**	2.5	0.0	0.0	158
Soil fertility management	46.2 **I**	8.9 **III**	8.9 **III**	32.3 **II**	3.6	0.0	0.0	303
General crop husbandry	25.9 **II**	20.1 **III**	15.6	34.6 **I**	3.8	0.0	0.0	680
Post harvest handling	43.9 **I**	0.6	29.0 **II**	23.9 **III**	2.5	0.0	0.0	314
Marketing	26.8 **II**	3.3	60.7 **I**	1.1	0.0	8.2 **III**	0.0	183
Crop protection	14.4 **III**	4.2	33.3 **II**	43.2 **I**	4.8	0.0	0.0	333

[a] Bold roman numbers highlight the three most mentioned information sources for each farming practice

[b] Within each farming practice category, different topics were included (not presented). The farmers were asked to only mention the single, most important source of information for these topics. n refers to the total number of valid responses on the different topics within a farming practice category. Total number of respondents=211

Source: knowledge and information survey

Table 11 Summary of farmer information sources for production and marketing of potato in Ethiopia, North Shewa, South Shewa and East Hararghe zones, 2004

Farming practice	Most important source of information (%)						
	Own experience	Family member	Farmer own community	Extension / NGO	Research	Potato traders	n[c]
Potato varieties	3.0	14.8 **III**	58.7 **I**	17.9 **II**	5.5	0.0	797
Seed potato selection	57.3 **I**	24.3 **II**	15.6[b] **III**	2.8	–	–	1,109
Soil fertility management	63.7 **I**	15.3 **II**	11.1 **III**	6.3	2.9	0.7	1,128
General crop husbandry	59.2 **I**	16.2 **II**	16.1 **III**	4.8	3.4	0.4	3,203
Post harvest handling	62.9 **I**	17.0 **II**	9.2 **III**	5.9	4.2	0.7	707
Marketing	70.4 **I**	20.0 **II**	0.0	4.5	5.1 **III**	0.0	375
Crop protection	28.4 **II**	14.7	33.7 **I**	17.9 **III**	5.3	0.0	638

[a] Bold roman numbers highlight the three most mentioned information sources for each farming practice

[b] Includes research and traders

[c] Within each farming practice category, different topics were included (not presented). The farmers were asked to only mention the single, most important source of information for these topics. n refers to the total number of valid responses on the different topics within a farming practice category. Total number of respondents=646

Source: knowledge and information survey

information than in general crop husbandry practices. Only in Kenya the input suppliers were mentioned as a source of information on crop protection, which indicates that the input market for potato is relatively less developed than in other parts of the world.

In Kenya, commodity prices at wholesale markets are published through radio and newspapers, while farmers also received information from neighbours and family members. In Uganda, neighbouring farmers were the most important source of information on potato marketing and farmers in Ethiopia mostly relied on their own experience and that of their family members to source information for potato marketing, suggesting that there is a limited role of government or private services in the provision of this type of information to farmers.

The general observation can be made that the own farming community and family members are important sources of information on potato farming practices and techniques. Farmer-to-farmer information flow outside the farmer's own community or family, in contrast, is almost absent. The major actor facilitating access to potato-related information from outside the local community or family is the agricultural extension service. The direct contribution of research organizations to the knowledge and practices of potato farmers is modest but measurable. Considering their limited outreach, research organizations are required to work closely with NGOs and public extension services to ensure technological innovations have a reasonable chance of evolving outside the research organizations' chosen pilot testing areas. Publications and the media play a very marginal role in information exchange and knowledge development regarding farming practices. Even for technologies that require inputs, such as

soil fertility management and crop protection, the role of the supplier as a source of information is limited. Potato traders were not important as a source of information on potato farming, cultivars or marketing.

Important Actors in the Potato-Related Innovation Systems

During the stakeholder workshops the important actors and their roles in the potato innovation system were identified. The Kenyan potato-related innovation system was characterized by the presence of the public extension service of the ministry of agriculture as the sole institutional provider of information at the farmer level. The national research organization, an international research institute as well as a development donor collaborated with the ministry of agriculture in initiatives in the potato sector. There is a specific body for seed potato certification and several actors specifically intervening in the seed potato system. Other innovation system actors identified by the workshop participants who play less intensive and visible roles are potato traders, input suppliers, universities and local governments. Potato farmer organization is limited to self-help groups in the potato-growing zones. A national potato farmer association is attempting to establish and earn the mandate and recognition of the potato farmers as the organization representing them in lobbying and marketing. The producers, however, expressed reluctance and suspicion towards attempts to organize the farmers as a result of a long tradition with such organizations being used for the self-interest of its officials, rather than the interest of its members.

In Uganda, the potato knowledge and information system is characterized by a public extension service that is being replaced by a government-funded but privately delivered agricultural extension programme (National Agricultural Advisory Services, or NAADS) (Benin et al. 2007). Through a decentralization process local governments have become important actors in the agricultural system as indicated by the workshop participants. During the workshop several NGOs were identified that operate in the potato-production zones of southwestern Uganda, in different alliances with each other and the national and international research organizations, the private extension service delivery NAADS, the conventional extension services and the local government system (Gildemacher et al. 2009a). Consequently, there is a relatively strong interaction between different actors in the potato system. There is no formal seed potato certification system, but there are several actors specifically intervening in the seed potato system. As in Kenya, potato traders and agro-input suppliers were hardly recognized as key actors in the knowledge and information system. Farmer organization is, as in Kenya, largely limited to self-help groups.

The Ethiopian system was characterized by a centralized organization of both research and public extension. Non-governmental intervention was coordinated at a macro level by the central government. In spite of this central coordination, there was limited interaction between agricultural research, public extension services and NGOs, which was identified as a major obstacle for potato system innovation during the stakeholder workshop. In different potato-growing areas, universities are active in the potato sector but also not always in coordination with the national research organization programmes. Farmer organization is limited although all farmers are by

default members of peasant associations, the lowest Ethiopian administrative unit. Potato traders and agro-input suppliers are few and judging from the stakeholder workshop outcomes as well as from Table 11, they hardly play a role in the potato knowledge and information system. The NGO and government bodies represented in the stakeholder meeting indicated prioritizing the organization of farmer unions and associations, but also indicated that this is complicated as they have to overcome farmer suspicion of such initiatives as a result of forced farmer organization under totalitarian rule in the recent past.

Potato Innovation System Constraints Identified

Woolthuis et al. (2005) developed a 'system failure framework' as a tool for policy recommendation in the industrialized world. The same approach was used for synthesizing the insights into the potato system in Kenya, Uganda and Ethiopia. Woolthuis et al. (2005) distinguished six different categories of system failure. These are infrastructure failure, hard institutional failure, soft institutional failure, strong network failure, weak network failure and capabilities failure. Infrastructural failures are constraints requiring major investments, with returns in the long term, that cannot be made by the actors of the system independently. 'Hard institutional failure' refers to rules and regulations, or the lack of them, hampering innovation, whereas 'soft institutional failure' refers to unwritten rules, or 'the way business is done'. 'Strong network failure' refers to actors 'locked' into their relationship, which blocks new ideas from outside and prohibits other potentially fruitful collaborations. 'Weak network failure' refers to a situation where actors are not well connected and 'fruitful cycles of learning and innovation may be prevented' (Woolthuis et al. 2005). Finally, capabilities failure points to the lack of technical and organizational capacity within the system to adapt to and manage new technology (Woolthuis et al. 2005).

In Table 12, the potato sector failures are presented according to these categories, using the information about the innovation system obtained through the stakeholder workshops, the surveys and expert opinion of other innovation system actors. The different types of system failures are cross-tabulated against the relevant innovation system actors, to provide a structured insight into the functioning of the system. Table 12 structures the shortcomings of the potato innovation system, and provides insight into the types of failures of the different important actors in the system. The failures per actor are briefly discussed below.

International Potato Center

The weaknesses of the International Potato Center (CIP) lie in the limited staff with a high turnover and severe limitations in research infrastructure in Africa. The strategy of CIP to deal with the low staff numbers is a strong focus on the national research organizations as partners, while there is fairly limited interaction with the private sector and the public extension services. CIP shares a high-tech focus with the national research organizations, which promotes a bias towards larger successful farmers. The limited staff numbers also result in relatively weak grassroots

connection of the institute within Africa. As a result of a rigid description and interpretation of the boundaries of its mandate, limited priority is given to capacity building of the other actors in the system and to the appropriate packaging and communication of research results (Table 12).

National Research Organizations

Although the national research organizations in the three countries differ significantly, there are commonalities in their failures in the system. Insufficient research facilities and seed potato production facilities are serious constraints according to the national researchers. In Kenya and Uganda, communication is reasonably good, although researchers rely largely on private mobile phones and Internet cafes for their communication. In Ethiopia, access to mobile phones and Internet cafes was less developed. Mobility is restricted owing to limited funds for vehicle replacement, maintenance and use, resulting in complaints by both farmers and extension workers that researchers do not respond quickly to their needs and are not visible in the field. The functioning of the national research organizations is further complicated by rigid administrative systems of the institutions as well as by donors that complicate the access to and effective spending of the limited available funds. The functioning of the research organizations is also hindered by a lack of performance-based rewarding of staff (Table 12).

Regional research collaboration exists, but potato researchers in the region indicate they experience severe constraints in communication, as well as in mobility within the region. Collaboration in crop improvement is hampered by rigid rules regarding cross-border exchange of germplasm and seed. Different regulations for potato cultivar release procedures in the three countries complicate the regional release and utilization of the same cultivars across the region. In Kenya, cultivar release regulations are overcomplicated.

The national research organizations are also biased towards high-tech problem-solving approaches. Additionally, interventions and research collaborations tend to target more successful and affluent farmers. CIP is the major source of innovative potato technologies for testing and adaptation in the national potato farming systems. Limited priority is given to the effective and appropriate communication of research results to end-users. Within the national research organizations there is a lack of capacity to facilitate stakeholder interactions, execute multidisciplinary research and perform impact assessments and evaluations of interventions.

Sharing of resources with extension partners is rare, except in a few specific projects. Collaboration with extension partners and farmers is mostly ad hoc and local, without a vision for maximizing the impact of innovative technology. Very limited interaction exists between the national research organizations and the private sector, partly because the private sector is poorly developed and partly as a result of mistrust.

Agricultural Extension Actors

The complex of agricultural extension actors includes the public agricultural extension services, private agricultural extension service providers and non-governmental organizations all engaged in agricultural extension activities. This is

Table 12 Identification of system failure in the potato related innovation system in Eastern Africa

Actors rules *(System failures)*	International research (CIP)	National research organizations	Extension (Public, private and NGO)	Potato growers	Private sector
Infrastructural failure (*constraints requiring major investments*)	• Low staff numbers • No research infrastructure Africa • No seed potato infrastructure	• Low staff numbers • Low mobility • Limited web access • Insufficient research infrastructure • Limited seed potato infrastructure	• Low staff numbers • Low mobility • No web access	• Bad roads • Poor marketing infrastructure • No storage capacity • Poor availability inputs (Ug & Et) • No credit facilities • Limited processing	• Bad roads • Poor marketing infrastructure • No credit facilities
Hard institutional failure (*formal, written, consciously created rules of conduct and interaction*)	• Limited responsiveness resulting from funding mechanisms • Narrow interpretation of research mandate	• Rigid administrative systems • No cross country germplasm exchange • Complicated variety release (Ke)	• Limited responsiveness due to rigid mandates and intervention areas • Centralized resource flows	• Complicated seed potato certification (Ke) • Lack of farmer organization	• Lack of quality standards • Lack of professional body
Soft institutional failure (*informal rules of conduct and interaction*)	• Hierarchical perception of roles of actors • A high tech bias • Large farmer bias • Fast staff turnover • Low priority for capacity building partners • Low priority communication of research results	• Hierarchical perception of roles actors • High tech bias • Large farmer bias • Acceptance sub-optimal functioning organization • No resource sharing • No performance based staff rewarding • Limited international orientation and innovative thinking • Low priority communication of research results	• Hierarchical perception of roles actors • High tech bias • Large farmer bias • No resource sharing • No performance based rewarding (public ext.) • Limited faith in farmer capacities • Passive role in research • Fast staff turnover (NGO) • Short planning horizon (NGO)	• Acceptance poor bargaining power • Acceptance current production and knowledge level • Mistrust of farmer organizations (Ke, Et) • Limited trust extension service • Passive information receivers • Lack of incentives for higher quality production	• Acceptance low quality potatoes • Acceptance imperfect marketing systems

Strong network failure (*strong ties between actors hampering interaction with outside actors)*	• Single focus on national research organizations as partners	• Single focus on public extension as "messenger" of technological innovation • Single focus on CIP for delivery of ideas, resources and new technology	• Single focus on national research as a source of new information • No pro-active project acquisition or search for partnership	• Single focus of farmers on extension for clean seed and information.	• Single focus on traders and middlemen as source of potatoes
Weak network failure (*limited interaction between actors*)	• No interaction with private sector • Poor grass-roots connection • Limited interaction with public extension	• No interaction with private sector • Localized grass-roots and public extension interaction	• No interaction with private sector • Limited and passive interaction with research • Limited interaction with selective group of farmers • No interaction with private sector	• No interaction with private sector • Limited interaction outside of the community • No farmer organization	• No interaction with producers • No interaction with extension • No interaction with research
Human capacity failure (*essential skills missing for playing an effective role in the innovation system*)	• Limited capacity for hands-on on-the-job capacity building of collaborators	• No innovative thinking	• Limited capacity in participatory approaches / adult learning / group dynamics	• Very low education levels	• No research capacity
	• Limited capacity to design and test communication strategies	• Low multidisciplinary research capacity • No skills for packaging and communicating research skills • Limited stakeholder interaction management capacity • No impact assessment / evaluation	• No capacity to develop training materials / methods • Limited stakeholder interaction management capacity • Low organizational capacity • No impact assessment / evaluation	• Illiteracy • Limited experience and incentive to innovate • No organizational skills	• No skills in participatory interaction with smallholder farmers

a heterogeneous group with different limitations in their roles in the potato system in the three countries. The limitations were identified in the stakeholder workshops and through the consultation with the actors.

The public extension service suffers from low staff numbers and the mobility of the limited staff is very poor as they lack transport means. In all three countries extension workers lack communication means and have no access to professional information. In Kenya and Uganda, the functioning of extension workers is further complicated by continuous reorganization of administrative structures. In Uganda, the public extension services have been largely dismantled in favour of the contracting of 'private extension service providers' under the NAADS programme (Benin et al. 2007). In all three countries, farmers complained of limited access to the extension staff. When asked about the major problems in sourcing information, farmers most often mentioned the lack of presence in the field of extension workers.

All extension actors are limited by the specific mandates they have through project financing, mostly so the private service providers in Uganda and NGOs, who are bound to contracts and project-defined intervention areas. This tended to leave out many potential beneficiaries. The system also tended to the same bias as researcher organizations of favouring affluent or successful farmers.

The public extension services and private service providers look unilaterally to the national research organizations for solutions to problems indicated by farmers, and as indicated in the workshops they are disappointed in the response time of research. Like the other actors, the extension services lack contact with private sector partners and there is mistrust between them and potato traders and input suppliers. In both Kenya and Ethiopia, extension workers explicitly indicated that input suppliers cheat potato farmers. Furthermore, they felt that input suppliers do not have the skills to play a role as sources of information on potato production.

In general, the capacity and experience of the agricultural extension workers in participatory approaches, adult learning techniques and group dynamics was low. Like the national research organizations, the extension organizations lack the capacity to develop appropriate training methods and materials. They have low organizational capacity and limited experience in managing stakeholder interaction. With the exception of non-governmental organizations, no impact assessment and project evaluation is practised routinely.

Potato Growers

The interests of potato growers are not represented by any professional body in the three countries. Farmers in the region are not organized beyond village-based self-help groups. As a result of this lack of organization of potato producers at a higher level, they importantly lack clout in potato marketing as well as in the general potato-related innovation system.

During the stakeholder workshops, farmers indicated that poor rural road infrastructure and the poor marketing infrastructure adversely affect the potato market. In the absence of on-farm ware potato storage facilities, market information and farmer organizations, farmers are not able to bargain for better prices with middlemen. Marketing infrastructure is limited in all three countries, but most particularly in Ethiopia, where farmers transport and sell their potato produce

piecemeal to buyers at local village markets (Table 6). At the same time, researchers and NGO workers indicated the absence of wholesale markets for potatoes in the capital in Ethiopia.

In Kenya and Uganda, there are traders who collect and sell potato to wholesalers in urban markets. There are hardly any alternatives to farmers other than to market their produce for the fresh potato market, especially in Ethiopia and Uganda. In Kenya, a limited processing industry for crisps and an infant industry for frozen French fries exist (Hoeffler and Maingi 2005). Potato farmers lack access to credit facilities in all three countries. This was put high on the list of priorities by farmers in the Kenyan stakeholder workshops. In Uganda, access to inputs is limited for farmers as both fungicides and fertilizers are hardly available outside the main town centres. Farmers in Ethiopia indicated that unavailability of fungicides when they are most needed in rural areas is a major constraint.

Access to high-quality seed potatoes is cumbersome for potato farmers in all three countries, and was mentioned by producers and extension workers as a major bottleneck for potato production. In the stakeholder workshops in both Kenya and Ethiopia, producers and extension workers blamed the inadequate production and distribution of high-quality seed potatoes squarely on the research organizations.

Direct contact between producers and retailers or processors of potatoes is limited to a few cases initiated through development projects at considerable effort. The existing marketing situation does not provide much incentive for innovation. Farmers accept the current low levels in knowledge and production and are in general not proactive in seeking collaboration with extension services which they do not hold in very high regard, with the notable exception of NGOs who have been distributing improved potato cultivars and high-quality seed.

Private Sector

Although potato producers could also be considered private entrepreneurs, the private sector is here understood to be those actors that commercially deliver goods and services to the potato production chain, other than potato production. This comprises agro-input and output marketing and processing.

Most importantly, the processing and retailing sector indicates suffering from irregular and poor-quality supply of potatoes. There are no standards for potato grading and packaging or even cultivar names on which potato wholesalers, retailers and processors could rely when judging quality. Furthermore, representatives of the output marketing and processing sector in Kenya identified the lack of potato storage facilities as an important problem. The private sector actors are not organized in a professional body representing their interests that could function as a first contact point for the other actors that may desire to interact with them.

The private sector largely relies on informal brokering, transporting and wholesaling systems that exist in the countries, with limited interference to optimize the commodity flow. The majority of private sector actors have no interaction with potato producers, with the exception of input retailers and field-level potato brokers. Few private sector actors interact with research and extension organizations, with the exception of a few specific individuals.

Discussion and Conclusions

Potato Production and Marketing

This research has shown that potato production provides smallholder farmers in the East African highlands with a profitable exploitation of their scarce land and capital, as most farmers get a higher return on their labour by growing potatoes than they would get by hiring out their labour. Considering the limitations to increasing the share of arable land to potatoes, especially in Kenya and Uganda, an increase in productivity per unit area is required to offset rising demand for potatoes in Kenya, Uganda and Ethiopia.

Four technical intervention areas were identified which could lead to improved productivity as a result of technological innovation. These included seed potato quality management, bacterial wilt control, late blight control and soil fertility management.

Potato Innovation System

Improving productivity alone will not result in a dramatic improvement of profitability of potato production. Marketing was a prime concern of potato farmers, and logically a major driver of decisions. Technical innovation in conjunction with marketing intervention would increase the probability of successful intervention in the smallholder potato system in Kenya, Uganda and Ethiopia. The current innovation system has internal flaws that could hamper development of solutions to the production and marketing constraints of the potato sector.

An important feature of the potato-related innovation system is the combination of soft institutional and strong and weak network failure in the relationship between the research organizations, extension services and farmers in the system (Table 12). There is 'soft institutional failure' in the sense that each actor has a fairly conservative narrow interpretation of its and others' roles, along the linear transfer of technology model, already criticized by Chambers (1983). Chambers identified the 'normal professionalism' of agricultural scientists as the cause of the domination of the ineffective linear transfer of technology model. Hierarchical thinking about actor roles, large farmer bias and the related high-tech bias are elements of this 'normal professionalism'. From the system analysis in the region, it is evident that not only researchers and extension workers but also potato farmers suffer from hierarchical thinking about the roles of actors.

The potato-related innovation system suffers simultaneously from 'strong network failure' and 'weak network failure'. On the one hand, research, public and NGO extension actors and farmers do not look beyond their horizons for solutions to problems. Simultaneously, there is weak network failure in the form of the lack of productive partnerships between private sector partners and research, extension services and producers. This combined with the static interpretation of each others' roles limits the chances of system innovation through new ideas.

To overcome network failures, facilitation of stakeholder interaction through a potato platform was identified as a priority in the three stakeholder meetings (Gildemacher et al. 2009a). Impartial intermediaries could be considered to

improve the interaction and coordination of the innovation system. These have been shown to be well positioned to restore the functioning of an innovation system (Klerkx and Leeuwis 2008). A difference from the system described by Klerkx and Leeuwis (2008) is, however, that the potato innovation systems in the three countries are hardly privatized, and there is a collaborative rather than a competitive sentiment between the most important potato system actors. As such, an impartial intermediary may not be essential and another option could be for one of the actors to take on the role of a system broker, and champion the potato innovation system improvement.

There is a clear need for smallholder potato producers to unite themselves to raise their clout in both knowledge-demand articulation as well as in marketing. Their organization at a higher level is pivotal to the success of improved innovation system functioning. Considering the low level of training of the average potato producer, the organizational capacity of the producers is limited and effective farmer organization is thus unlikely to be initiated without professional support. A starting point for the formation of an umbrella potato farmers association could be the current rudimentary, village-level self-help groups present in all three countries.

In spite of the widely acknowledged criticism of the linear transfer of technology model, extension services, in whichever form, are an important and necessary link between end-users and agricultural research, both for demand articulation as well as for the communication of innovative technology. The extension services need to get involved in technical innovation efforts to tackle the four technical constraints to productivity increase. The other innovation system actors should take into consideration the limited mobility and the low level of training of field workers.

Research and extension partners realized they lack the capacity to translate research insights and pilot experiences of research and development partners into generically useful training materials that could support and facilitate a wider adoption of innovations. The potato sector in the three countries therefore should not only focus on its technical research capacity, but should simultaneously develop skills and commit resources to improvement of the service delivery to potato producers.

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