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African farmer-led irrigation development: re-framing agricultural policy and investment?

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The past decade has witnessed an intensifying focus on the development of irrigation in sub-Saharan Africa. It follows a 20-year hiatus in the wake of disappointing irrigation performance during the 1970s and 1980s. Persistent low productivity in African agriculture and vulnerability of African food supplies to increasing instability in international commodity markets are driving pan-African agricultural investment initiatives, such as the Comprehensive Africa Agricultural Development Programme (CAADP), that identify as a priority the improvement in reliability of water control for agriculture. The paper argues that, for such initiatives to be effective, there needs to be a re-appraisal of current dynamics of irrigation development in sub-Saharan Africa, particularly with respect to the role of small-scale producers' initiatives in expanding irrigation. The paper reviews the principal forms such initiatives take and argues that official narratives and statistics on African irrigation often underestimate the extent of such activities. The paper identifies five key characteristics which, it argues, contradict widely held assumptions that inform irrigation policy in Africa. The paper concludes by offering a definition of 'farmer-led irrigation' that embraces a range of interaction between producers and commercial, government and non-government agencies, and identifies priority areas for research on the growth potential and impact of such interactions and strategies for their future development.

Keywords: irrigation; sub-Saharan Africa; small-scale agriculture; technology innovation

1. Introduction

After a 20-year hiatus in public investment in irrigation in sub-Saharan Africa (SSA) (Faures, Svendsen, and Turral 2007), the wheel started to turn again in the late 2000s. Recent studies have focused on the scope and constraints for irrigation development in SSA (Inocencio et al. 2007; You et al. 2011; Fujiie et al. 2011; Xie et al. 2014) feeding the policy debate around the type of investment that would be the most desirable and appropriate to the SSA context (Lankford 2009). Various pan-African studies and policy processes ran parallel to each other (Lankford 2005; Inocencio et al. 2007; AfDB et al. 2008; AgWa 2010), while contributing momentum to the development of the Comprehensive Africa Agriculture Development Programme (CAADP), a continent-wide programme developed under the African Union's New Partnership for Africa's Development (NEPAD) initiative. The programme is organised through four pillars, of which the first is 'extending the area under sustainable land management and reliable water control systems'[1] (NEPAD 2003). Simultaneously, new ambitious national policies for irrigation investment were developed in SSA countries (for Kenya, GoK 2015; for Tanzania, URT 2013; for Mozambique, Républica de Moçambique 2015). Bilateral and other international funders also turned their attention to irrigation, and agricultural water management more broadly (Giordano et al. 2012; World Bank 2006). The 2008 World Development Report called for reinvesting in the agricultural sector, notably in SSA, where agricultural productivity had remained stagnant over the last few decades (World Bank 2007). The same year, the 2008 food crisis served as another reminder of the failure to increase productivity of African agriculture during the previous two decades. An alliance of five influential international organisations[2] called for large-scale new investments into irrigation (AfDB et al. 2008).

Irrigation therefore is back on the agenda. However, there is a tendency in such advocacy to suggest that large-scale investment is required to achieve a significant increase in the irrigated area.[3] Besides public investment, expectations of large-scale private (foreign) investments are especially high (for instance, World Bank 2011). In this paper we argue that this agenda ignores farmers' initiatives in developing irrigation already widespread throughout SSA. That small-scale farmers make substantial investments in productive assets in agriculture aligns with arguments recently made by, amongst others, Reij, Scoones, and Toulmin (2013), Peters (2013) and Woodhouse (2012). These investments involve actively engaging with (irrigation) technologies and external (support) networks as well as integrating into local and international markets, as argued by Edelman (2014) and Van der Ploeg (2014).

A better understanding of farmers' irrigation initiatives opens an alternative to current dominant narratives that emphasise large-scale public and private investment programmes – one that we argue offers better prospects for progressive change. By 'progressive' we mean change that generates benefits that are widely distributed among the rural population and sustained over the medium to long term. In making such a claim we are aware that there is nothing inherently egalitarian about 'local' initiatives to raise agricultural productivity, which are as likely to precipitate processes of socio-economic differentiation and competition for land and other resources (Woodhouse, Bernstein, and Hulme 2000; Peters 2004; Li 2014). The broader significance of farmers' irrigation initiatives are that they not only challenge stereotypes of small-scale agriculture as 'stagnant' and destined to decline (Collier and Dercon, 2014), but also pose questions about the political and economic dynamics of agrarian change driven 'from below', and how these may be interpreted in relation to classical concerns of political economy with accumulation and class formation. We seek to identify elements of a research agenda to address those questions at the end of this paper. Initially, however, we need to examine to what extent farmers' irrigation initiatives are even recognised by planners and policy-makers. And here we identify three blind spots – conceptual constraints – that make it difficult for current framings of irrigation in SSA to engage effectively with farmers' initiatives. Firstly, irrigation in Africa is

[1]The other three are: improving rural infrastructure and market access; increasing food supply and reducing hunger; and agricultural research and technology dissemination.

[2]The World Bank, the African Development Bank (AfDB), the Food and Agricultural Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD) and the International Water Management Institute (IWMI).

[3]Given the historically high cost of investments in large-scale public irrigation systems (Inocencio et al. 2007), the CAADP prioritizes 'the identification and preparation of investments to support small-scale irrigation' (NEPAD 2003, 28). However, it still highlights that significant investments are needed in aggregate terms.

commonly characterised as falling short of an Asian benchmark. Secondly, the 'transfer of technology' from elsewhere is often envisaged as the solution. And, thirdly, a dichotomy is created between irrigated farming and rain-fed farming, which does not do justice to the many in-between forms of agricultural water management that constitute farmers' actual practice.

The first of these conceptual shortcomings typically highlights SSA's large 'irrigation potential', while contrasting the limited extent of actual irrigation in Africa compared to Asia (in terms of water use, stored water, equipped irrigated area and percentage of irrigable area actually irrigated). This implicitly sets Asia as a 'model' that should be replicated in Africa (as exemplified by the use of the term 'second green revolution' or '(Alliance for an) African Green Revolution'). While the experience of Asia may provide important lessons for irrigation policy in Africa, there are risks that a focus on the ways in which Africa 'falls short' compared to Asia precludes a discussion of the actually existing irrigation practices in Africa. There are grounds to be wary of such comparisons, not least because official measures of irrigated areas may be inaccurate in many African countries as we illustrate later in the paper (see also Lankford 2005; Veldwisch, Beekman, and Bolding 2013; Giordano et al. 2012). Given this, it follows that (1) referring to farmer-led irrigation as 'small-scale' seems misleading and (2) nations with ambitious targets for increasing their irrigated area may actually already be well on their way to achieving them, yet are unlikely to be aware of this.

The second 'transfer of technology' blind spot is underpinned by a conceptualisation of irrigation as a technological package necessary to invest in to transform agriculture as a whole. Investment in large-scale irrigation systems is expensive (Inocencio et al. 2007), and, because of its scale and complexity, requires the involvement of an external agency (be it a government, a non-governmental organisation (NGO) or a development agency). According to this model, what needs to be transferred is not only a technology (dams, canals, pumps), but also institutions: investment can only be made productive if subsistence smallholders are turned into rural entrepreneurs, which can only happen if they have formal (i.e. state-backed) land rights and easy access to formal (preferably urban) markets. Here, rather than a manifestation of diverse socio-technical adaptations to specific contexts, irrigation development is seen as requiring the transformation of much of the existing rural fabric. That minor changes to (or even unaltered) social arrangements can also produce transformative changes is not recognised. The role that farmers are already playing in irrigation development is underestimated as farmers are framed as 'beneficiaries' rather than as 'agents' of irrigation.

The third blind spot relates to the definition of 'what makes irrigation'. Here again, the Asian 'benchmark' plays a critical role and irrigation in SSA often comes to be defined as the area for which physical infrastructure allows for 'total water control'. The Aquastat database of the FAO, for instance, differentiates between areas with 'total' or 'partial' water control, the first one being 'equipped' for irrigation, but overlooks the diversity of irrigation practices in SSA highlighted by Adams (1992), among others. In the dominant narratives and statistical data, small adjustments made by farmers, for instance when supplying water to crops during dry spells in the rainy season, do not qualify as irrigation.

In contrast to this dominant narrative, we draw on a growing body of evidence to show a multiplicity of situations in which farmers play a leading role in irrigation development in SSA. While much of this literature is recent, some key sources date back to work done in the late 1980s and early 1990s that focused on small-scale irrigation as a viable alternative to large-scale projects whose benefits were increasingly being questioned (Carter 1989; Adams 1991; Moris and Thom 1985; Adams and Anderson 1988; Adams 1992; Diemer and Vincent 1992). Lessons drawn from these studies have often been ignored by current irrigation development strategies (see Veldwisch, Bolding, and Wester 2009 for a critical analysis of a large irrigation scheme in Malawi). This contribution builds on that work and extends it by studying current farmers' initiatives and how they come about, and the opportunities and constraints associated with them.

We define 'farmer-led irrigation development' as a process where farmers assume a driving role in improving their water use for agriculture by bringing about changes in knowledge production, technology use, investment patterns and market linkages, and the governance of land and water. In the process, farmers rely on and influence neighbouring farmers, agro-dealers and traders, craftspeople, agriculture extension agents and irrigation engineers, administrative authorities, local and national policy-makers, civil society and development aid agents. By doing so we complement but also extend other recent studies that described farmers' initiatives in developing and using specific irrigation technologies, and identified the factors that made these developments possible or hindered them (De Fraiture and Giordano 2014). We show that this is not limited to horticultural production, but also includes staple grains such as maize and rice. Throughout the paper we use the word 'irrigation' to refer to a wide array of water control techniques practiced in agriculture, including 'partial control' methods such as spate and sub-surface irrigation.

In the next section we present four examples of farmer-led irrigation development, each with widespread significance. In each case, we focus on a particular case study but also link it to a wider body of literature that has documented similar processes in other countries/regions of SSA. In section 3 we consider five characteristics of farmers' investment in irrigation that run through multiple instances and challenge common assumptions on irrigation in SSA. These five features are that (1) farmers invest substantially in irrigation; (2) in the process farmers interact with 'outside' agencies that influence and shape rural economic dynamics; (3) farmers innovate as part of broad socio-technical networks; (4) irrigation development does not require formal land tenure; and (5) despite many farmers benefiting from self-developed irrigation, others may be adversely affected. In the concluding section, we re-visit our definition of farmer-led irrigation development and propose a new research agenda grounded in this perspective on farmers' irrigation development. This, we argue, has wider significance for broader debates regarding smallholder agriculture, food sovereignty and innovation dynamics in development.

2. Examples of farmers' irrigation initiatives

2.1. *Furrow irrigation in mountainous areas*

In mountainous areas in East and Southern Africa, the last two decades have witnessed rapid expansion of furrow irrigation systems using water diverted from permanent mountain streams. Examples of these can be found in central Mozambique bordering on (and into) Zimbabwe; in the Angonia area of Mozambique, bordering Malawi; and on the slopes of Kilimanjaro in Tanzania and in Kerio valley in Kenya. This type of furrow irrigation has a long history, in Tanzania and Kenya dating back centuries before colonial rule (Adams and Anderson 1988; Adams, Potkanski, and Sutton 1994; Tagseth 2008a, 2008b, 2010), in Zimbabwe and Mozambique from the beginning of the twentieth century. Research suggests significant recent expansion of these systems: Beekman, Veldwisch, and Bolding (2014) suggest that in the Mozambican border area with Zimbabwe, there are currently more than 100,000 ha irrigated in this manner.

The operation of these systems may be illustrated by research in the upper catchment of the Revue River in Mozambique (Schippers 2008; Bolding, Post Uiterweer, and Schippers

2010; Beekman, Veldwisch, and Bolding 2014). Typically, several furrow irrigation systems take water from one stream, sometimes additionally capturing water from side streams, springs or neighbouring catchments. These systems are interlinked, whether indirectly through seepage and return flows of excess water to the river, or through direct interlinking of several furrow systems, presenting a picture of a complex socio-hydrological network – as the communities using these furrow systems are also intertwined (Van der Zaag, Bolding, and Manzungu 2001; Bolding, Post Uiterweer, and Schippers 2010) – rather than a series of separate irrigation systems. Periods of drought, or of above-average rainfall, often occurring in cycles of several years (Schippers 2008), lead to shrinkage or growth of irrigated area (Bolding, Post Uiterweer, and Schippers 2010; Lankford and Beale 2007). Apart from responses to such climatic variations, patterns of migration and resettlement generate a dynamic reconfiguration of the systems, physically changing the furrows in time and space (Bolding, Post Uiterweer, and Schippers 2010). Almost all farmers use these systems to produce crops for the market during the dry season, often using chemical inputs to enhance production (Beekman 2011; Van den Pol 2012).

The emergence of irrigation in these mountainous areas of Mozambique is significant in that, historically, these areas have been safe havens for people fleeing repressive labour conditions in Mozambique during colonial times, or escaping insecurity in Rhodesia in the 1970s and Zimbabwe in 2002–2005. The current phase of repopulation, since 1992, is mainly by Mozambican 'outsiders', including farmworkers returning to Mozambique following Zimbabwe's 'Fast Track' land reforms. Zimbabwean nationals are excluded from acquiring land but allowed to settle, providing cheap skilled labour (Bolding, Post Uiterweer, and Schippers 2010). In Mozambique, as population densities increase, an 'upstream migration' can be observed whereby farmers introduce terracing and new irrigation systems in the upstream areas (Schippers 2008). In Tanzania, it is the contrary: as population density increases, the furrow systems expand ever farther downstream. Water and land rights are often established by initial investments. The first constructor(s) become the 'owner(s) of the canal', often in charge of regulating maintenance and water distribution within the canal. The construction of new systems, or improvement of old ones, often attracts new users and an associated reconfiguration of rules on irrigation practices at both furrow and catchment levels (Bolding, Post Uiterweer, and Schippers 2010; Beekman 2011; see also Nkoka, Veldwisch, and Bolding 2014 for cases in Angonia, Mozambique). New canal users often buy themselves in or extend the canals. Water rights are maintained by investment in operation and maintenance, and non-compliance can lead to exclusion of farmers from water (Schippers 2008; Bolding, Post Uiterweer, and Schippers 2010). Thus far, such conflicts that arise appear to have been managed mostly within local customary governance arrangements, since few examples are known where disputes have resulted in formal government intervention or litigation through the courts (Bolding, Post Uiterweer, and Schippers 2010). However, these systems have been largely overlooked by the state as they are imbedded in 'informal' trading networks largely unreported and beyond the purview of formal policy circles.

2.2. *The use of shallow groundwater in valley bottoms*

Relatively wet valley bottoms in regions that are otherwise dry during a substantial period of the year exist in various SSA countries and are known to be sites of agricultural intensification (Woodhouse, Bernstein, and Hulme 2000). Such areas have a variety of names in different countries: *bolis* in Sierra Leone, *fadama* in Nigeria, *bas fonds* in Niger, Mali and

Burkina Faso, the Swahili term *mbuga* in East Africa and *vlei* in Zimbabwe and South Africa. In Malawi, as in a number of other Southern African countries, they are referred to as *dambos*, the chi-Chewa term for 'meadow grazing land' (Von der Heyden 2004). The World Bank has promoted the use of pumps and boreholes for irrigation in the extensive *fadamas* of northern Nigeria since the 1980s (Carter, Carr, and Kay 1983; Carter 1989), so that by 2004 Vermillion (2004, 5) claimed that *fadama* irrigation accounted for 114,000 ha, or more than half of the total 220,000 ha irrigation estimated for Nigeria as a whole. However, even without such international support, the past 40 years have seen a gradual shift elsewhere in SSA in the use of such valley bottoms from dry-season grazing to intensive dry-season production of vegetables,[4] in some cases in the face of government opposition (see Bell et al. 1987 for Zimbabwe). In this respect, the use of *dambos* in Malawi is representative: until the 1940s, *dambos* were considered to be marginal lands of little value and mainly used for livestock grazing. They are nowadays largely used for intensive smallholder cultivation (Wood and Thawe 2013) and FAO (2015) estimates the area of such 'non-equipped' cultivated wetlands and valley bottoms at 61,900 ha, comparable to the 73,000 ha of 'full-control irrigation' in Malawi. Consequently, they are now highly valued and sites of struggles for ownership (Peters and Kambewa 2007).

Veldman's (2012) study of Badwa *Dambo* usefully illustrates farmer-led development of dambos in Malawi. Farmers draw water either from a natural drain in the middle of the *dambo* or from shallow wells, excavated to a depth ranging between 1.5 and 5.0 m and with diameters typically between 1.0 and 2.5 m. High population density and the relatively small size of *dambos* means most farmers have small *dambo* plots known as 'dimba gardens', averaging between 0.28 ha for the poorest and 0.64 ha for the wealthiest, on which they prioritise crops for their own consumption, and then increase production by multiplying cropping cycles in order to be able to market a surplus. Crops grown include tomato and lettuce, beans, groundnut, sweet potato, tobacco and maize – the latter typically grown in the dry season for sale as 'green maize' on the cob. Watering cans and treadle pumps are used to raise water onto the fields. During the wet season, drainage canals may be constructed to drain excess water. At some locations, especially where a dam or bridge is constructed, standing water remains and can be used for fishing, bathing or washing clothes. At the start of the dry season crops grow on residual moisture in the soil, but by June and July most farmers start to water their crops from the wells, depending on the location within the *dambo* and the type of crop being grown. By the end of the dry season the main drain is completely dry and in most wells water levels have dropped to more than 2 m below field level. Veldman's study identified three drivers of intensification of *dambo* use: firstly, increasing population leading to heightened land pressure and, especially during dry years, higher risks of food shortages; secondly, growing urban markets, meaning high-value crops can be sold. Many farmers sell their produce through middlemen, thus saving time and money for transport. A large group of highly active farmers also market their produce themselves, transporting it by bicycle, minibus and sometimes even on foot, either at a nearby trading centre or in Lilongwe. And, thirdly, secure markets make capital investment into agriculture less risky, and increasing water use and the resulting desiccation of *dambos* makes it possible (and/or necessary) to extend cultivation to the centre of the wetland area.

[4]Valley bottoms are classically used during the wet season for rice cultivation, with limited water control.

2.3. *Petrol pump irrigation from open water bodies and shallow groundwater*

In the past two decades petrol pumps have quickly emerged as an irrigation technology that smallholder farmers use to pump from open water bodies, such as lakes and rivers, to provide water for intensive horticultural production. Observations throughout SSA suggest that this is a widespread phenomenon (Giordano et al. 2012). In some places, notably valley bottoms with shallow ground water, access to water is created by digging shallow wells. Petrol pump irrigation by small farmers has, for instance, been well documented for Ghana (Schraven 2010; Laube, Schraven, and Awo 2012; Namara et al. 2014), Zambia (Colenbrander and van Koppen 2013) and Ethiopia (Dessalegn and Merrey 2015). In the case of Burkina Faso, small pumps drawing water directly from reservoirs behind small dams (Venot, De Fraiture, and Nti-Acheampong 2012) may often irrigate upstream areas one to two orders of magnitude larger than the canal-based irrigated area downstream that the dams were designed to supply (De Fraiture et al. 2014).

A representative example of pump irrigation is provided by Bosma (2015) who analysed how horticultural production emerged in Western Kenya along a 13-km stretch of the shore of Lake Victoria, providing an alternative to declining fisheries and hence an important alternative economic opportunity for young people in the area. Responding to a growing market for vegetables both locally and in the regional urban centre of Kisumu, 100 km away, small-scale producers have established commercial production of tomatoes, kale, fruit, indigenous vegetables and, more recently, watermelon and capsicum. Despite some volatility, markets for vegetables can be profitable, and groups of 15–40 farmers have expanded their cultivation from about 100 m^2 per farmer to between 0.25 and 0.75 ha each and 10–25 ha for each group.

The increasing availability of petrol pumps over the past 20 years, driven by farmers' demand and increased supply through agro-dealers' networks in local towns, has been a key factor in the development of commercial horticulture production. Local shops sell pumps across a range of price (USD 180–570) and size (HP 2.5–7). The cheap Japanese pumps, and even cheaper Chinese copies, have made pumps affordable for many, but some farmers invest in more expensive pumps to gain quality and reliability (and also to achieve status). Most farmers prefer to own their own pumps, but others borrow or rent pumps, or co-own a pump with one or more other farmers. The development of irrigation using motorised pumps in SSA is primarily driven by farmers' own initiatives and their ability to tap into a supporting network of small retailers and agricultural merchants. In some countries, such as Malawi, however, it has also been significantly facilitated by national trade policies, such as duty-free imports of irrigation equipment.

2.4. *(Peri-)urban agriculture using waste water*

Rising demand for fresh fruit and vegetables has driven increased local production in and around almost all African urban centres (Drechsel and Keraita 2014) and is mostly met by an informal sector of small-scale horticultural producers. These often make use of waste water, diluted or raw, creating serious health risks, both for those handling the water and for consumers buying the products of such irrigation. Despite this, and other hazards, small-scale producers have developed substantial irrigated areas, sometimes moving across the city to new production sites when they are pushed out from their plots by construction projects. As a result, total areas of production may be relatively stable, as has been documented for the case of Dar es Salaam (Drechsel and Dongus 2010).

Ghana has a notable history of the state recognising, and to some extent supporting, from the 1970s onwards, urban agriculture as a means to contribute to meeting food demands (Danso et al. 2014a). In the late 1990s, the Ministry of Food and Agriculture established local offices in all cities and staffed them with agricultural extension workers. Currently, in Accra and its surrounding area there are some 800 to 1000 vegetable farmers involved in the production of both exotic vegetables (including lettuce, cabbage, spring onions and cauliflower) and local vegetables (including tomatoes, okra, aubergine and chilli peppers) (Danso et al. 2014a). Watering cans are the most common technology used (Keraita and Cofie 2014). Though laborious, this technology often suffices for the generally very small plot sizes in the city, which range between 0.01 and 0.02 ha per farmer (Danso, Hope, and Drechsel 2014b). Motorised pumps are reported to be used increasingly, especially where farmers can share a pump and where distances between the water source and the fields are large. Even in these cases, farmers continue to use the watering cans, drawing from a reservoir on the farm that is filled by the pump (Keraita and Cofie 2014). Drechsel and Keraita (2014, 3) estimate that, in Ghana as a whole, 'the beneficiaries of urban vegetable production are up to 2,000 urban farmers, 5,300 street food sellers, and 800,000 daily consumers within the major cities plus an unknown number of traders', based on an irrigated area of up to 40,000 ha.

3. Five characteristics of farmers' investment in irrigation

3.1. *Farmers invest substantially*

The cases we have reviewed above are part of a mounting body of evidence highlighting that African farmers make significant investments of labour and capital in developing irrigation both at household and aggregate levels. As illustrated above, this includes, but is not limited to, construction and maintenance of irrigation canals, purchase and maintenance of small water pumps to lift water from surface and groundwater sources, and management of flooding and drainage of low-lying wetlands.

In aggregate, these small-scale investments may have significant cumulative effects on overall irrigation development. We noted above the extensive development of *fadama* irrigation in Nigeria. In Ghana as well, Namara et al. (2014) report that official import data show that over 65,000 pumps and accessories were imported between 2003 and 2010, worth more than USD 8 million. This is of the same order of magnitude as investment in a large irrigation project. In a separate piece of work, these same authors calculated that 186,000 ha may be irrigated by means of water-lifting technologies, involving 500,000 people. This type of farmer-led irrigation development alone is already more than 10 times bigger than public irrigation systems in Ghana, which total 13,000 ha, involving some 11,000 families (Namara et al. 2011).

Because of the informal nature of many of these activities, they do not feature in clear or consistent ways in national statistics. For example, on the basis of field research in Central Mozambique, Beekman, Veldwisch, and Bolding (2014) infer that about 115,000 ha of undocumented farmer-led irrigation may exist country-wide. This would double the officially recognised area of irrigation in Mozambique, which, in 2012, stood at 118,000 ha (Beekman, Veldwisch, and Bolding 2014). Official government statistics from Tanzania demonstrate a similar issue. Reported levels of agricultural activity based on Tanzania's Living Standards Measurement Survey (LSMS) do not match the areas of irrigation implied by the same source. This is illustrated by data for paddy rice, a crop that requires some level of agricultural water management (in any of the forms that we have broadly defined above). Yet, of the 489 rice farmers (of just over 3280 in the nationally representative LSMS sample) recorded in the LSMS, only 19 are reported by the LSMS as using irrigation. This suggests that the survey is capturing only 3 percent of actual rice irrigation practice. The same problem, and the same sort of deficit, appears in Tanzania's two large agricultural censuses of 2002/2003 and 2007/2008. These cover 53,070 and 56,235 households, respectively (the numbers are larger because these surveys are regionally as well as nationally representative). In the 2002/2003 census, 89 percent of rice farms appear to be unirrigated; in the 2007/2008 census, 94 percent of the paddy rice area is said to have received no irrigation.[5] Another way of putting these observations is that the irrigated rice area in Tanzania might be between 10 and 20 times larger than reported, depending on the definition and categories of irrigation considered.

Moreover, this analysis only pertains to rice. It does not include the missed irrigation of vegetable crops, maize and beans that have been observed in other studies. These areas may thus be part of irrigation systems that are not recognised as such by the government, enumerators or farmers, and who may therefore fail to identify them as 'irrigation'. This further reinforces our argument that farmers are likely to be more active with respect to irrigation development than is officially registered.

3.2. *Interactions among farmers, external agencies and the rural economy*

Though farmers invest substantially, the empirical examples briefly outlined in section 2 above also suggest that a dichotomy between 'external' and 'internal' (farmers' own) investment needs to be replaced by an understanding of irrigation development as a range of interactions between government, donor and non-government agencies, markets and the rural economy, and farmers.

Investments by farmers rarely, if ever, happen in complete isolation. Sometimes they respond to changes in agriculture or irrigation, but more often than not they are responding to changes in the broader socio-economic environment. This means that decisions to invest may be guided by economic factors, rather than those of 'agroecological potential' or 'irrigation potential' defined according to biophysical criteria that underpin 'land-use classifications'. As a consequence, the possibility of producing (some) crops for predominantly home consumption during the rainy season does not preclude investment in irrigation for commercial purposes, and vice versa. Production for the market may also reinforce food security considerations, either directly in terms of food for own consumption, or via cash income. Such a 'systemic' view locates irrigation development within a broader production system including (potentially) rain-fed crops and livestock, and household income and expenditure flows throughout the year. This is analysed by Van den Pol (2012) in central Mozambique and by Obuobie and Hope (2014) in Ghana who concluded that seasonal vegetable production in urban Tamale is for farmers a supplement to staple crop farming.

Much work is needed to elucidate such processes, but evidence so far suggests that development policy initiatives, (reduced) taxes on importation of water pumps, road improvements to reduce transport costs and increase access to markets, and regulation of food imports all have influenced farmers' investment in irrigation. For instance, the

[5]In the 2002/2003 census, 1486 ha of paddy rice were recorded as irrigated, while 14,009 ha were recorded as not irrigated. In the 2007/2008 census, the areas of paddy rice recorded were 3218 ha irrigated and 57,234 ha not irrigated. Source: Agricultural Sample Census Data 2002/3 and 2007/8. (unweighted data). Tanzania National Bureau of Statistics, 2016.

'groundswell of pumps' in Burkina Faso cannot be disassociated from the existence of more than 1000 reservoirs in the country, which make water available, and which have been built and rehabilitated by the government and its development partners (Venot, de Fraiture, and Nti-Acheampong 2012). Similarly, irrigators in the mountainous areas of Tanzania have long sought (and gained) support from NGOs and government to modernise their furrow systems. The role of wider economic factors is recognised by Bolding, Post Uiterweer, and Schippers (2010), who highlight that development of furrow irrigation in central Mozambique was partly linked to an increase in minibus movements and informal (artisanal) gold mining in the region. Another way of putting these points is that irrigation development derives from changes that are embedded in the local social fabric, and not predicated on a transformation of it.

Access to 'markets' clearly plays a key role, as farmer-led irrigation development often consists of producing high-value horticultural crops. It is, however, important to note that the nature of such markets may be informal and seasonal, embedded in networks of informal traders, rather than resting on registered businesses for storage and processing. Nkoka, Veldwisch, and Bolding (2014) demonstrate that farmer-led furrow irrigation development in Tsangano, near Mozambique's northern border with Malawi, increased rapidly under the influence of informal regional market links for the sale of potatoes in Malawi, Zambia and even Tanzania. Good markets for horticultural products in Accra (and almost all other African urban centres) are the driver behind urban and peri-urban vegetable production using waste water (Drechsel and Keraita 2014). Finally, Van den Pol (2012) showed that rapid development of new furrow irrigation systems in Messica, central Mozambique, was stimulated by credit and input supply linkages between farmers and informal trading networks in Chimoio.

Another way farmer-led irrigation development is related to the broader socio-economic environment is through labour mobility, which has long been a central characteristic of rural economies. Migration of labour has historically played a key role in agricultural intensification in Africa (Hill 1963; Swindell 1978) also including in large-scale irrigation development in the Gezira scheme in Sudan (Robertson 1987), in the Office du Niger of Mali (Aw and Diemer 2005), and in the Delta of the Senegal River (Engelhard and Ben Abdallah 1986). In contemporary farmer-led irrigation development, large numbers of immigrants make investment in construction possible. Examples include construction of diversion weirs and bench terraces made feasible by an inflow of Zimbabwean immigrants in the Penha Longa area of Mozambique (Bolding, Post Uiterweer, and Schippers 2010), and the clearance of bush by immigrant tenant farmers to create new fields in the Sourou valley in Mali (Woodhouse, Trench, and Tessougué 2000). Labour mobility also increases the capacity to cultivate large areas, as migrant farmers often are sharecroppers or tenants growing their own crops, or even hired labourers. In Accra, for instance, many labourers employed by urban vegetable growers are young migrants from Burkina Faso (Danso et al. 2014a). By the same token, the increased labour demands of irrigated production may result in greater retention of labour in areas previously subject to emigration. In Northern Ghana, the farmer-led development of shallow groundwater irrigation has been associated with a reversal in rural-urban migration (Laube, Schraven, and Awo 2012). Bosma (2015) also suggests young people engaged in horticultural production are now more likely to stay in their traditional fishing communities along Lake Victoria.

3.3. *Innovation in broad socio-technical networks and complex agricultural systems*

As a result of the 'systemic logic' of farmers' investment initiatives noted in the previous section, farmers are likely to develop different water resources and areas than those usually identified in 'irrigation potential' studies (Beekman, Veldwisch, and Bolding 2014). They are more inclined to take into account the ease of development, maintenance and operation, individually or within a small group. This leads, for instance, to a preference for developing irrigation on land with relatively steep slopes, using small streams, stable open water sources or wetland areas (because this combination makes it easier to move water around), instead of looking for large flat areas and abundantly flowing rivers as classic irrigation potential studies and development projects tend to do.

The different case studies highlight that irrigation innovations are integral to social networks that involve landholders, tenant farmers, intermediaries such as pump-owners, traders, masons and mechanics, and agents from governmental, non-governmental and international organisations. Evidence of farmers' initiatives in irrigation shows they copy water management technologies (the knowledge of which is being greatly enhanced by migration) and adapt them to local circumstances. Innovation thus takes place in a fairly open way with significant roles for 'knowledge brokers' with connections outside the immediate farming context.

This does not mean that farmers do not tap into engineering advice and support, where available. For instance, in several West African countries petrol pump irrigation developed in a dynamic triangle of relations between pump owners, land owners and cultivators (De Fraiture et al. 2014). Namara et al. (2014) describe in Ghana a network, functioning on market principles, in which 'pumps can be rented for a day, for a season, for a year or even on an hourly basis' (197). Bosma (2015) demonstrates the important role of mechanics and agro-dealers in the provision of petrol pumps in Western Kenya. The role of intermediaries such as wholesale vegetable traders is also crucial in stimulating farmer-led irrigation development through the provision of cash and inputs credit, as analysed by Van den Pol (2012) in central Mozambique.

3.4. *Formal land tenure is not a prerequisite for irrigation development*

A pervasive orthodoxy is that formalised land rights are a precondition for agricultural investment (World Bank 1989), despite this being widely questioned. Peters (2013, 541) has already shown that in West Africa '[a]gricultural intensification and commercial production were not inhibited by customary landholding'. Studies of farmer-led irrigation development across SSA also support this view. Clear examples are found in peri-urban horticultural production with waste water, which is expanding despite serious tenure insecurity and non-agricultural (urban construction) land demands (Drechsel and Keraita 2014). In rural settings, and in various Sahelian countries, young people are given the chance through informal land arrangements to produce horticultural crops by making use of water reservoirs in the dry season (De Fraiture et al. 2014). On the shores of Lake Victoria, in Western Kenya, petrol pump irrigation is mostly based on temporarily rented land (Bosma 2015). In central Mozambique, settlers acquire land that is hardly ever formally registered, and even through transactions outside traditional institutions governing land tenure (Bolding, Post Uiterweer, and Schippers 2010; Van den Pol 2012). In all these cases, individuals engage in short-season transactions to assemble land, equipment, labour and other inputs to produce crops for the market. Though these arrangements are often negotiated on a seasonal basis, they appear to be sustained over several years or even decades.

What is equally clear is that these arrangements do not imply a comprehensive 'communal' governance of land and water, whereby the latter would be seen as 'commons'. As we have already observed, agricultural intensification is associated with high levels of migration, and markets for labour and land. This often happens within a framework of customary authority, consistent with what have been termed ‘vernacular land markets’ (Chimhowu and Woodhouse 2006). These suggest highly individualistic decision-making according to a variety of entrepreneurial logics mediated by a degree of adaptation (bricolage) of existing governance institutions, of both state and custom (Cleaver 2002).

Issues of legitimacy and legality are risks in such situations, and may become critical if conflicts arise. At the very least they pose questions about the longer term stability, sustainability and equity dimensions of farmer-led irrigation development. More fundamentally, this understanding of institutional adaptation challenges two prevailing views of governance of irrigation: on the one hand formalisation of institutions such as land rights and water management committees; on the other hand the assumption of stable customary hierarchies capable of resolving conflicts over land and water use to satisfy different parties.

3.5. *Many benefit, but others are adversely affected*

In the preceding sub-sections we have shown that farmer-led irrigation is widespread, and explained how it develops. Despite some farmers benefiting from these developments, it is likely that others may be negatively affected, notably as customary land and water rights become redefined and contested (Woodhouse 2003). Three types of negative impacts may be identified: (1) local effects, such as land being alienated, intra-household re-distribution of burdens and benefits (Carney 1998); (2) downstream effects, such as reduced water flows and water pollution (Lankford et al. 2004; De Fraiture et al. 2014); and (3) other dislocated effects, such as reduced prices for agricultural produce or food safety issues as a result of waste-water use (Drechsel and Keraita 2014).

Some well-known cases include complaints that the 2400 ha Lower Moshi public irrigation scheme has not been getting sufficient water as result of some 1400 ha of upstream swamp area being developed for intensive rice cultivation by farmers themselves (Ikegami 2001). Similarly, farmer-led irrigation development upstream of small reservoirs in Burkina Faso is often blamed for leading to declining water quality and availability in the canal-based irrigation systems located downstream of these same reservoirs (De Fraiture et al. 2014). There are signs of institutions evolving to address such issues. For example, in the north Pare Mountains, Tanzania, farmers using water in a shared furrow negotiated that upstream villages are allowed to divert river water from 6 am–4 pm, leaving the remaining hours (4 pm–6 am) to downstream villages (Komakech, Van der Zaag, and Van Koppen 2012). Similarly, on the slopes of Kilimanjaro and Meru, river committees have emerged to allocate and monitor water use, and solve water conflicts between different users of a particular river (Komakech and Van der Zaag 2011; Komakech et al. 2012) using either time-based or proportional allocation to share water between furrows. Within a furrow, individuals’ water allocation is based on participation in maintenance activities, payment of seasonal fees and the water requirement of his/her crop. There is also evidence of formalisation of such local institutions, as the Tanzanian Water Policy (2002) and Water Resources Management Act (2009) have recognised customary arrangements and seek to nest them within statutory river basin management structures.

4. Conclusions and a research agenda

4.1. *Re-framing irrigation development*

In the above we show that significant farmer-led irrigation expansion is taking place in SSA, to an extent that is largely underestimated by state agencies, development organisations and researchers. The conditions under which this is happening and the dynamics of its development diverge from models of irrigation understood by many irrigation development experts and framed in policy documents. This demands further examination of how we define the phenomenon and how we pursue its further investigation. Earlier, we defined farmer-led irrigation development as a process where farmers assume a driving role in improving their water-use for agriculture by bringing about changes in knowledge production, technology use, investment patterns and market linkages, and the governance of land and water. In the process, farmers exhibit entrepreneurial and risk-taking behaviour and interact with a range of other actors. This definition acknowledges that, from a farmer's perspective, this is intentional development that requires work and investment. In that respect it is certainly not 'spontaneous' nor 'unplanned'. In emphasising processes through which irrigated agriculture comes about, rather than categories describing what the resultant irrigation looks like, our definition of farmer-led irrigation development highlights the social interactions underpinning it: farmers take a leading role, but always in collaboration with other actors and sometimes directly building upon (earlier) investments by state, private or civil society actors. Thus, these processes often manifest hybrid forms of collaboration that are not purely private, public or communal. The resultant irrigation is sometimes very localised, but in other situations expands over large areas, often displaying the characteristics of interconnected socio-hydraulic networks.

A consequence of adopting this perspective on irrigation development is that many dichotomies that have characterised debates about irrigation in SSA become irrelevant. We argue, for instance, that polarised discussions around terms such as small- and large-scale, formal or informal, and community-based or state-led irrigation are distractions from an understanding of the dynamics of actually existing irrigation in specific contexts. Indeed, the basis of irrigation statistics in categories rather than processes makes it difficult to identify farmer-led irrigation in them. In the next section we seek to identify elements of an agenda for further study.

4.2. *Studying farmer-led irrigation*

The understanding that farmers have an active role in driving irrigation development in SSA opens up a new research field in which we identify seven initial questions.

First, our understanding that these initiatives do not take place in isolation poses a question about the modes in which farmers and external agencies relate to each other and how their interactions shape irrigation development. In addressing this question, we recognise that state and wider governance systems are not monolithic, but are rather made up of interconnected, but often fragmented, 'policy domains' that may respond in different, and possibly contradictory, ways to farmers' initiatives. Policy interventions and the organisations and individuals involved in their elaboration and implementation are inspired by ideals and work towards objectives such as 'irrigation development', 'community development', 'agricultural development' and 'natural resources management'. These are what we call 'policy domains', each typically run by distinct agencies and with their own paradigms and goals. A second question, then, relates to the ways different development models and ideals (e.g. arising from different policy domains) shape (for instance via narratives and discursive practice) agencies' engagement with farmers' initiatives. A third related question would then ask how these diverse development narratives play out in influencing irrigation practices and vice versa, and how irrigation realities may in turn contribute to an emerging debate on the modalities of innovation in development (Venot 2016) that includes questions related to the frontier of state and expert (engineering) control over technology development, and of the agency of smallholders in shaping development realities.

As we observed above, groups of farmers are heterogeneous both in their aspiration and in their ability to derive benefits from irrigated agriculture. Some are less able to exploit opportunities, despite (or because of) innovation going on around them, than others. Further, people can be involved in a variety of different roles, including being excluded (by choice or force). Not all take the role of 'farmers', but may take other roles: intermediaries and brokers, delivering water, inputs, marketing opportunities or knowledge. A fourth research question therefore asks how different groups of farmers engage with farmer-led irrigation initiatives, including (different forms of) exclusion, and studies the outcomes this has for their assets and abilities to derive benefits from agriculture. These questions lay the ground for analysing the dynamics of social differentiation between and within households, as well as across regions and communities, that characterise farmer-led irrigation development, and, critically, the extent to which these dynamics differ from those of state-led interventions.

In practice, it seems likely that individual irrigators will need to agree on some form of collective rules to manage shared water resources. A fifth research question then arises about how tensions between individual, entrepreneurial decision making and some level of collective action – mediated through state or customary structures – are negotiated in practice, and what requirements (transparency? equity? safeguards for the vulnerable?) would need to be met for the outcome to be recognised as legitimate both locally and within a state-backed framework of governance – and hence 'legal', even if operated through 'community' or 'customary' structures. What such a governance framework would look like, and through what process it could be constituted, can only be investigated through emerging experience.

A sixth question would then ask whether the answers to the first five justify a broader attempt to identify a typology of farmer-led irrigation, not on the basis of their scale, technology, product or market integration, but in terms of the processes of development and differentiated engagements with the state and wider governance systems. Finally, a seventh question would ask how significant and representative these findings are at a national scale, and more broadly in SSA.

4.3. *Contributing to broader debates*

Our chief concern in writing this paper is to establish that farmer-led irrigation development is simultaneously taking place across different SSA countries and policy contexts, in diverse agro-ecological zones and landscapes, and engaging with a number of agricultural value chains, without (major) external planning by the state or development agencies. We further argue that recognising farmer-led irrigation development has important implications for debates about the present and future role of smallholders in African rural development. The absence of a 'green revolution' in Africa is a key factor in arguments that smallholder agriculture has no long-term future in African agriculture (e.g. Collier and Dercon 2014). Acknowledging farmer-led irrigation development challenges narratives of small-scale agriculture as 'stagnant' and suggests a more fruitful analysis of patterns of investment through which small-scale agriculture is already changing. Here, the comparison with Asia's – and particularly India's – green revolution is important. For contemporary proponents of 'Africa's green revolution', the problem is fundamentally about identifying a technical 'package' and its means of delivery via extension and input supply. This seeks to find an African equivalent of India's green revolution 'package' of increased fertiliser application to high-yielding wheat and rice varieties grown with 'optimal' irrigation (delivered by means of privately owned diesel or electric pumps from boreholes). Yet in India the technical character of green revolution transformations was soon overtaken by an awareness of the profound social changes it involved, and, in particular, the growing differentiation between those able to gain access to capital to invest in pumps and boreholes, and those who could not (Pearse 1980; Harriss-White and Harriss 2007). It is these social dimensions of 'accumulation from below', creating capitalist farmers on the one hand and classes of rural labour on the other, that have, in part, fueled contemporary movements, such as 'food sovereignty', that see technologies generated by 'western science' as threatening and that therefore seek greater control by 'smallholders' over their own production processes (Edelman 2014), including the property relations in land, water and infrastructure investment (Boelens and Vos 2014).

The absence in Africa of a 'green revolution' following this Asian model is taken to signify 'stagnation' in a technological sense, but is also read by some as a lack of socio-economic differentiation in rural areas, as evident in the recent 'land grab' literature (De Schutter 2011; Woodhouse 2012). This is despite the overwhelming evidence of socio-economic differentiation in African rural areas, particularly as a result of differential access to non-farm income that is the principal source of capital for agricultural investment (Reardon 1997; Murton 1999; Ellis 2000; Ellis and Freeman 2005). That irrigation development in Africa has not been the focus of such processes of differentiation is due on the one hand to the predominance of the 'Gezira' model in which large-scale schemes are managed by state agencies renting plots to small-scale tenants producing under contract, exemplified by the Office du Niger (Aw and Diemer 2005), and on the other hand by the comparative failure of productivity in many irrigation investments in Africa, to which we referred at the start of the paper. While the large-scale model lives on, strictures on African state budgets since the 1990s mean dependency on foreign investment and emphasis on crops with export potential. There is evidence that such export-oriented agriculture can provide large-scale employment that benefits poorer rural people, particularly in labour-intensive vegetable production and packing enterprises (Maertens and Swinnen 2009). In other cases, however, employment opportunities are limited by mechanisation and 'local beneficiaries' of irrigation development are increasingly constituted by 'outgrowers' whose role is to rent their land to agricultural corporations, as exemplified by the expansion of irrigated sugar cane production in southern Africa (Dubb, Scoones, and Woodhouse forthcoming).

It is in this context that the observation of widespread 'farmer-led' irrigation development in SSA is a possible signifier not only of quickening investment in raising productivity (and associated changes in market access), but also of new and powerful forces for social change in rural areas. In arguing that these changes offer scope for more 'progressive' change, signifying more widely distributed benefits, we have emphasised that this is not to assume any inherent egalitarian qualities in farmer-led irrigation development. Indeed, our 'research agenda' sketched in the previous section draws on Bernstein's (2014) critique of food sovereignty proponents' portrayal of the peasantry as a unified, singular social category. The argument we have set out in this paper is that if increasing agency of African farmers in developing irrigation leads to better adaptation and more cost-effective irrigation, the assessment of social and economic effects must start from an understanding of the diversity of possible axes of differentiation, such as gender, ethnicity, length of residence, access to capital and technical knowledge and the social dynamics of accumulation or impoverishment to which they give rise in specific contexts.

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ORCID

Philip Woodhouse http://orcid.org/0000-0002-6238-2724

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After training as an agricultural scientist at Oxford (BA) and Reading (PhD), **Philip Woodhouse** worked in Mozambique for the National Agronomy Research Institute and the Food and Agriculture Organization of the United Nations. Since returning to the UK he was based first at the Open University and subsequently at Manchester. He has undertaken research on land and water management in a number of countries in Francophone West Africa, southern Africa and East Africa. He has also collaborated on research in Brazil. Email: phil.woodhouse@manchester.ac.uk

After training in irrigation management and institutions at the University of Bonn, **Gert Jan Veldwisch** worked for the International Centre for Tropical Agriculture (CIAT) in Chimoio, Mozambique, before moving to Wageningen University. Gert Jan works in the field of irrigation and development, currently in Southern and Eastern Africa, but has also worked in Latin America and Central Asia. His research interest is in participatory irrigation development, irrigation and agrarian change and issues around water justice. Email: gertjan.veldwisch@wur.nl

Jean-Philippe Venot trained in agronomy and environmental management (Institut National Agronomique de Paris-Grignon), and human geography (University of Paris X-Nanterre). He worked for the International Water Management Institute (IWMI) in Ghana and Burkina Faso and then at the University of Wageningen, where he remains an associate. Currently a senior researcher at the Institut de Recherche pour le Developpement in Montpellier, France, his research focuses on public policy and development interventions in the irrigation and water sectors in developing countries, most recently on drip irrigation in sub-Saharan Africa and irrigation management transfer in South-east Asia. Email: jean-philippe.venot@ird.fr

After training as an anthropologist at University College London, **Dan Brockington** worked at the geography departments of the universities of Cambridge and Oxford, before moving to Manchester and then Sheffield. Most of his research has been in Tanzania, where he has worked on livelihood change, natural resource governance, microfinance and institutional performance. He has also worked in South Africa, Australia, New Zealand and India. Broader interests include work on global overviews of the social impacts of protected areas, media and conservation and continental-wide examinations of the work of conservation non-governmental organisations (NGOs) in sub-Saharan Africa. Email: d.brockington@sheffield.ac.uk

Hans Komakech trained as a civil engineer at Makerere University and obtained his PhD in water resources and management at UNESCO-IHE Institute for Water Education (Delft, Netherlands). He has worked as project manager and consultant engineer on project design and implementation with international NGOs. He is currently lecturer on integrated watershed management in the Department of Water, Environmental Science and Engineering (WESE) at the Nelson Mandela African Institute of Science and Technology, Tanzania. His research focuses on water governance institutions in national and transboundary basins, water allocation issues in catchment areas, and point-of-use water treatment and safe storage. Email: hans.komakech@nm-aist.ac.tz

Ângela Manjichi trained in agronomic engineering (Eduardo Mondlane University, Mozambique), and in environmental management (University of Notre Dame, Australia), before becoming assistant lecturer in rural extension and development at Instituto Superior Politécnico de Manica (ISPM). She is currently General Director for Academics and Research and assistant lecturer in the Department of Agriculture at ISPM. She also directs the Business Incubator Centre and co-ordinates ISPM's Unit for Gender and HIV/AIDS. Ângela's research is focused on sustainable development, natural resource management, and climate change and environmental education. Email: amanjichi@gmail.com