The ‘Majaluba’ Rice Production System: A Rainwater Harvesting ‘Bright Spot’ in Tanzania

John Gowing, Lisa Bunclark, Henry Mahoo and Frederick Kahimba

Abstract The rainwater harvesting technique under consideration here is an example of intermediate-scale external catchment runoff harvesting. The focus for discussion is on the ‘*majaluba*’ system which is found in Tanzania and comprises a network of roughly level basins each surrounded by an earth bund. Basins are arranged in the landscape in order to collect local runoff from stony outcrops and grazing lands in upslope areas with cattle tracks often used as conduits. The ‘*majaluba*’ system is used primarily for the production of rainfed lowland rice. It has spread through autonomous diffusion of knowledge from farmer to farmer since its introduction in the 1930s. The estimated extent of this system is around 600,000 ha which contributes 60% of total rice production in Tanzania. This is a remarkable, but little known, success story, and represents a water harvesting ‘bright spot,’ where sustainable intensification of smallholder agriculture has been achieved at scale.

Keywords Agriculture · Sustainable intensification · Meso-catchment
Runoff harvesting · Technology adoption

1 Introduction

Numerous authors have proposed definitions of rainwater harvesting (RWH), but there is generally very little difference between them. We adopt the definition proposed by Critchley and Scheierling (2012): ‘The collection and concentration of rainfall runoff, or floodwaters, for plant production.’ Similarly, many authors have

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attempted to classify RWH technologies into a broad typology (e.g., Boers and Ben Asher 1982; Gowing et al 1999; Oweis and Hachum 2009). A distinction is often made between techniques on the basis of where the runoff is collected and how far it is diverted. Runoff may be collected from fields, hillslopes, house roofs, rocks, pavements, roads and tracks, or ephemeral streams and gullies. Rainfall may be captured locally on the farm where it is to be used, or as runoff from rain that falls beyond the farm boundary which is then transferred to the farm over distances that vary from tens of meters to several kilometers. RWH practices may also be distinguished on the basis of how the captured water is stored; this is often within the crop's root zone, but may be in a storage pond (or tank) or in a shallow aquifer. We adopt the typology shown in Fig. 1.

The RWH technique under consideration here is classified as meso-catchment runoff harvesting. The *majaluba* (sometimes known as *majaruba*) RWH system is found extensively in Tanzania and is used primarily for the production of rainfed lowland rice in bunded basins. Hillslope runoff is collected from stony outcrops and grazing lands in upslope areas with cattle tracks often used as conduits (Fig. 2). It is believed to have originated in Sukumaland (Lake Victoria Basin) and is arguably not a 'traditional' practice, since it seems to have been introduced by Asian migrant workers during the colonial era (Shaka et al. 1996). It is a remarkable, but little known, success story—a 'bright spot' for RWH. Its adoption and spread without external intervention can be seen as indicative of the potential of appropriate RWH practices to deliver sustainable intensification of dryland cropping systems.

There are documented examples around the globe of agricultural innovations that have been effective in achieving positive impacts on rural livelihoods and food security (Pretty et al. 2006, 2011). These so-called bright spots provide evidence of successful adoption of novel agricultural practices at the level of the community (village, district, or catchment). Evidence from these documented bright spots contrasts with the general picture of agricultural stagnation in sub-Saharan Africa (SSA) (Wiggins 2014). As noted by NEPAD (2010), there is an urgent need to put in place a strategy to scale up these and other local-level successes in order to have a significant impact on the interrelated problems of land degradation, declining agricultural productivity, and rural poverty.

Pretty et al. (2006, 2011) reported analyses from 20 countries in Africa where sustainable intensification has been developed, promoted, or practiced. By early 2010, these projects had documented benefits for 10.4 million farmers and their families on approximately 12.7 million hectares. Their intention was to investigate the processes and outcomes on a large enough area and across enough farms to draw some common conclusions about how to develop productive and sustainable agricultural systems and how to scale these up to reach many more people in the future. Their 40 case studies represented various types of innovation and included a small number of examples of RWH.

The *majaluba* case study presented here can be seen as a contribution to the knowledge base on RWH 'bright spots,' where sustainable intensification of smallholder agriculture has been achieved at scale. We will describe the RWH

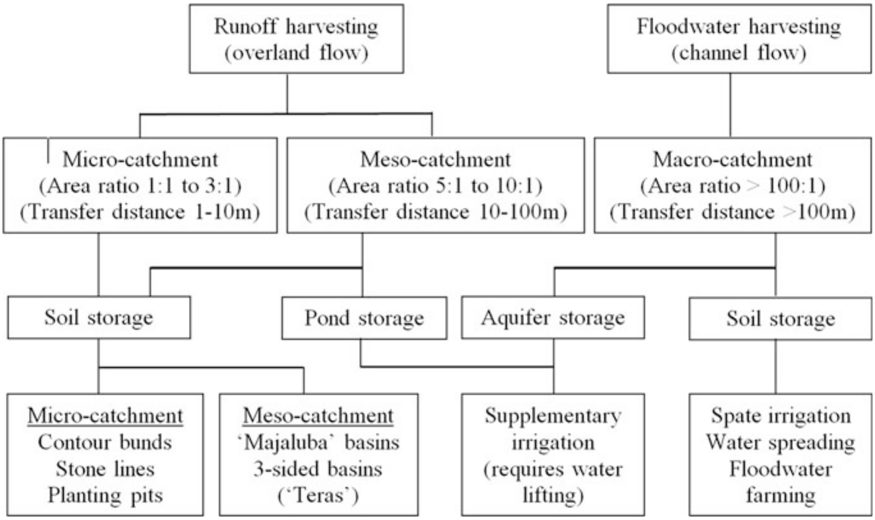

Fig. 1 Typology of rainwater harvesting systems

system, review evidence of its expansion, and current extent and consider the importance of its contribution to rice production in Tanzania.

2 Methodology

2.1 Study Area

The study area covered the central corridor of Tanzania (Fig. 2), which contributes 60% of the total rice production area (Government of Tanzania 2009). Three study sites were selected forming a northwest to southeast transect through the rice cultivation area. The most northern of the sites is Mwalogwabagore at approximately 30 km south of Lake Victoria in Mwanza Region and within the zone identified by Shaka et al. (1996) as being the origin of the *majaluba* system. Lali is located 200 km further south in Shinyanga Region and within the area described by Allnutt (1942). Lionii is close to the southern edge of the corridor at 60 km northeast of Dodoma and 300 km from Shinyanga.

The rainfall regime at the two northern sites is largely bimodal with a *Vuli* rainy season between October and December and *Masika* rainy season from March to May. Prolonged dry spells occur during January–February and a dry season during May–October. Average annual precipitation is between 800 and 900 mm. The most southerly site (Lionii) is located in the center of Tanzania, where there is a uni-modal rainfall regime with rainy season extending from October to April. Average annual precipitation in this region is less than 600 mm. All sites are in the

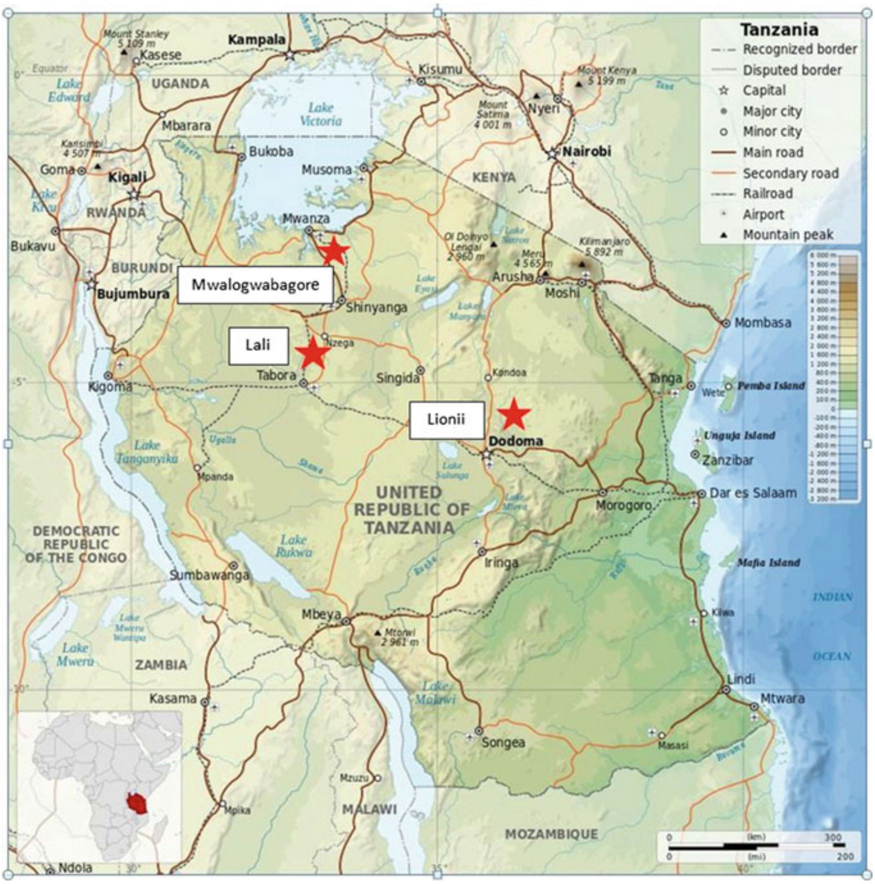

Fig. 2 Map showing location of fieldwork sites in Tanzania. *Source* © Sémhur/Wikimedia Commons/CC-BY-SA-3.0 (or Free Art License)

central plateau physiographic region (at 1000–1300 m altitude) (Basalirwa et al. 1999).

The landscape comprises a sequence of valleys interrupted by granite hills with slope lengths 1–3 km in narrow valleys and 5–6 km in broad valleys. Soil types vary systematically in relation to physiography. Indeed, the concept of the soil 'catena' (soil sequence from hilltop to valley bottom) was first described by Milne (1947) in Sukumaland. Local farmers recognize this effect and local soil classification corresponds closely to scientific understanding (Payton et al. 2003). The typical Sukuma catena consists of freely drained sandy loams (Arenosols) on granite hills, followed by slowly permeable Planosols on the foot-slopes and swelling clay Vertisols in the valley bottoms. A description of these soils is given by Meertens et al. (1996), who emphasize the importance of the hard-pan soils which characterize the 'cultivation steppe' (as originally identified by Milne 1947). An idealized cross section of a typical catena is shown in Fig. 3.

2.2 *Prior Knowledge of the* **Majaluba** *Water Harvesting System and Its Evolution*

The existence of the *majaluba* rice system was first reported by Allnutt (1942) in the Sukumaland region of Tanzania (i.e., the zone to the south of Mwanza). He reported in particular on Shinyanga District in the south of the region, where the system had been recently adopted by farmers. He noted that, 'ten years ago a rice grower in Shinyanga was almost a curiosity,' but that rice was more established as an important crop elsewhere in the region. Clearly, there was evidence of adoption and spread at that time. This supports the report by Shaka et al. (1996) that the *majaluba* system originated in the 1930s when 'a small number of Asian workers in the local [cotton] ginnery grew enough rice for their own purposes.' They describe the situation in Maswa District, which is further north, closer to Lake Victoria and about 200 km from Shinyanga. Meertens et al. (1996) presented a comprehensive account of the historical development of farming systems in Sukumaland, which provides further evidence of continuing expansion. They cite Rounce (1951), who reported a survey conducted in 1945 which found that rice growing was expanding at that time. They cite also Collinson (1963) who reported the growing importance of rice cultivation during the 1950s. They report their own survey evidence from four 'representative' villages in Kwimba District (between Mwanza and Shinyanga), which shows that the increase in rice cultivation continued up to 1990.

As reported by Meertens et al. (1996), *majaluba* comprise roughly level basins surrounded by an earth bund that is typically 0.25–1.0 m high. Fields are positioned so that water for irrigation can flow by gravity through the system. They can be used for growing any crops with a high need for water, but in most cases paddy rice is cultivated. For rice cultivation, *majaluba* are usually built on hardpans or in valley bottoms on clay soils (known locally as *mbuga*). Water used in these systems is generally obtained (or harvested) from ephemeral streams, gullies, upslope land, or cattle tracks. Water enters the system through an inlet or opening at the uppermost basin and fills this before any excess is allowed to flow lower down the system in sequence (usually by overflowing the top of the bunds, or at a specific bund portion with lowered level). Rainwater in the *majaluba* system is also harvested in situ in case of little or no runoff from outside the fields. Farmers have developed an arrangement within the landscape (see Fig. 4) which aims to achieve a balance between upslope catchment area and downslope crop area. The catchment zone is typically heavily grazed, as this helps to generate runoff, but the slope length is limited in order to avoid excessive flow rates and erosion. On very long slopes, it is common to find two or more segments of bunded fields separated by catchment zones (Shaka et al. 1996).

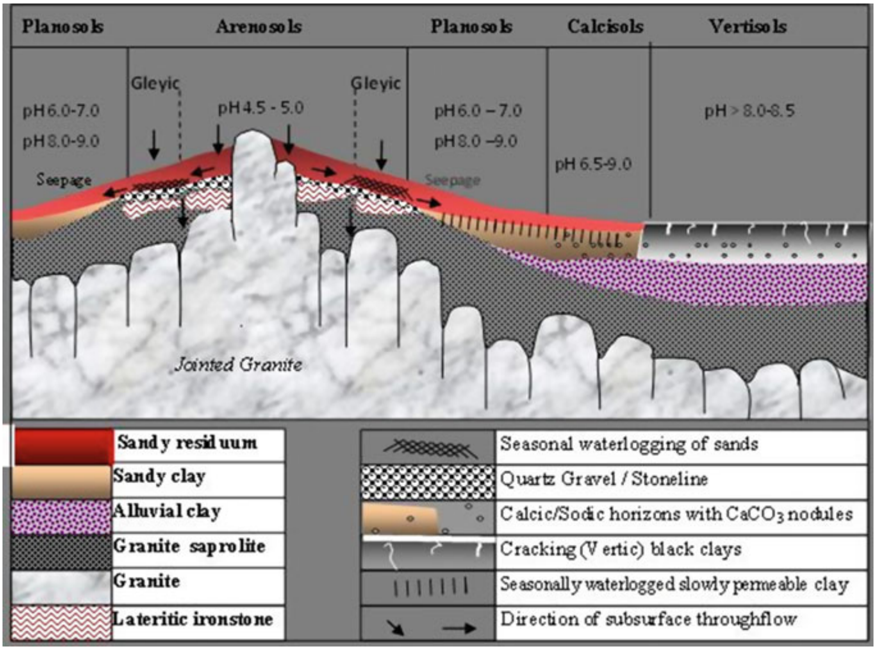

Fig. 3 Idealized cross section of a typical soil catena. *Source* (Payton 2000)

Fig. 4 View of *majaluba* water harvesting system. *Photograph* John Gowing

Farmers generally practice a mix of broadcast seeding and transplanting. As upper fields are the first to receive runoff, they often serve as nurseries and provide seedlings that can be used for transplanting and/or for gap filling in the lower fields. In good years, paddy yields of 2500 kg/ha are achieved, but water control is limited and in dry years some fields may remain fallow or may not provide a harvestable yield. Farmers generally aim to plant on the first rains, but if runoff is insufficient by December, it is unlikely that the crop will survive the January–February dry spells and in this case transplanting in March may be the best option (Meertens et al. 1996; Shaka et al. 1996).

2.3 Reappraisal Method

The purpose of the new appraisal was to gather empirical evidence that would allow us to explore whether the *majaluba* system has continued to expand beyond the extent reported by Meertens et al. (1996) and should indeed be viewed as a RWH ‘bright spot.’ Fieldwork was therefore conducted in Tanzania between September and October 2013 with the following research questions:

- Is the *majaluba* system still in use and still expanding?
- Where do farmers obtain technical advice on how to develop *majaluba*?
- What institutions are seen to influence the process of innovation?
- Is the change due to technology-push (e.g., technology promotion and performance) or demand-pull (e.g., need for more food, more money)?
- What factors exist to incentivize or constrain innovation?
- What are the impacts of this innovation on food and livelihood security?

Data collection at each site comprised participatory mapping and focus group discussions, transect walks, and key informant interviews. Separate focus groups (with twelve participants in each group) were held for men and women, in order to explore any gender-differentiated perceptions. Participants were chosen to represent households from a range of different socioeconomic, age, and livelihood groups with assistance from a local contact, which in most cases was the village (or hamlet) chairman. Farmers selected to participate were all heads of household or spouses; for the female focus groups, at least three participants in each were female heads of household. For the transect walk, five participants with in-depth knowledge of land-use patterns and land management of the village/hamlet were selected at each site. Key informants were identified via discussions with the village (or hamlet) chairman.

3 Results

3.1 Secondary Data on the Spread and Current Extent of the 'Majaluba' *RWH System*

Official statistics provide an unreliable indication of the extent and importance of RWH in Tanzania. According to FAO (2016), the area of land equipped for irrigation increased from 20,000 ha in 1961 (i.e., at the time of independence) to 363,514 ha in 2012. The main irrigated crops are maize and paddy rice, accounting for about 38 and 22% of the irrigated area (FAO 2016). Other irrigated crops comprise beans, vegetables (including onion, tomato, and leaf vegetables), bananas, and cotton. The following types of irrigation schemes are reported:

- Modern irrigation schemes (55,229 ha) are formally planned and designed schemes with full irrigation facilities and usually a strong element of management by the government or other external agencies. Those schemes are developed in the regions of Kilimanjaro, Morogoro, and Mbeya.
- Traditional irrigation schemes (117,000 ha) have been initiated and operated by the farmers themselves, with no intervention from external agencies. They include schemes based on traditional furrow irrigation for the production of fruit and vegetables in the highlands and simple water diversion schemes in the lowlands for maize and rice.
- Improved traditional irrigation schemes (190,285 ha) are traditional irrigation schemes on which, at some stage, there was intervention by an external agency, such as the construction of a new diversion structure.

The definition of 'traditional irrigation schemes' is problematic, as it is not clear whether RWH systems are consistently included or excluded. National estimates are derived from a sample census considering less than 30% of all villages and the definitions used for irrigated land (e.g., related to rainwater harvesting) appear to be inconsistent. FAO (2016) reports a separate category of 'rainwater harvesting-based schemes' with a total extent 27,200 ha in 2001 with no recent data. These are described as schemes where mainly paddy rice is grown using rainfall captured directly in small bunded basins or runoff diverted from residential areas, paths, and transient streams. The source of this estimated area is unclear.

Statistics for rice production are also available from FAOSTAT[1] and RICESTAT[2] databases, and they provide a different picture. The area of rice production has expanded over the same interval from 82,000 ha in 1961 to 925,000 ha in 2015. The data show some volatility in recent years, but the total area harvested is now around 1 million ha. Expansion was steady up to 2000, reaching around 400,000 ha, but there has been rapid growth since then. Total production in

[1] http://faostat.fao.org.

[2] http://ricestat.irri.org:8080/wrsv3/entrypoint.htm.

Tanzania is now around 1.2–1.4 million tonnes per year of milled rice (Nkuba et al. 2016).

Three major rice production systems are recognized in SSA (Diagne et al. 2013): irrigated, rainfed lowlands, and rainfed uplands. Reported data for rice production are not disaggregated by production system; however, Diagne et al. (2013) were able to disaggregate data for 2009 based on a farm household survey. For Tanzania, they reported, respectively, 27, 72, and 1% of the total rice production area. Clearly, the so-called lowland rainfed production system dominates and a similar analysis by Balasubramanian et al. (2007) using data for 1995–2004 also shows 73% contribution from 'rainfed wetland rice.' The question is then: What proportion of this total area (i.e., around 650,000–700,000 ha) actually corresponds to the 'majaluba' RWH system?

3.2 New Insights into the Spread and Current Extent of the 'Majaluba' RWH System

Use of *Majaluba* RWH system

Farmers in Mwalogwabagore and Lali reported that they were first exposed to rice cultivation by Asian migrant laborers in the early twentieth century. Farmers in Lionii adopted the technique in the 1980s after working in demonstration fields for an FAO project based in a neighboring hamlet (Bahi-Sokoni) around that time. In focus groups, farmers across all three sites said that they were driven to try the techniques as it allowed for converting previously unproductive land, largely used for communal livestock grazing, into highly productive cropland, providing both food and cash. The importance of rice production for income was said to have increased over the years, as explained in more detail below.

The whole family are involved in the cultivation of the paddy fields. Men tend to be responsible for preparing the fields for cultivation, clearing the land, building bunds, leveling the land, and plowing the soil ready for sowing/transplanting. Women were said to be primarily responsible for sowing seeds (either directly into the paddy field if broadcasting, or in a nursery bed if transplanting later), and weeding. Harvesting involves all family members. In all case study villages, farmers explained that most households tended to own a relatively large area of land in the lowlands, which was used for paddy cultivation. Typically, smaller areas of land were either owned or rented in the highlands to allow households to cultivate other staple crops, such as maize, sorghum, groundnuts, and cassava.

The arrangement of *majaluba* was said to be determined by the water availability and soil properties. Different-sized bunds are used to ensure that sufficient water for the crop is held, helping to prevent flooding or overdrying of the crop. Some fields depend on direct rainfall only, but most farmers channel rainfall runoff into their paddy fields where possible. Runoff is collected from the slopes above the *majaluba* fields, or from gullies carrying water from catchments in the uplands. In Lali, a few farmers were said to channel and store water in basins immediately upstream of their cultivated paddy fields, for supplementary irrigation. Some farmers with fields located in close proximity to the main road traversing Lali were also found to be diverting road runoff into their *majaluba* fields.

History of *majaluba* RWH system

In the beginning, rice was cultivated in small depressions close to the house that collected water during periods of rainfall. As cultivation expanded, farmers sought larger areas of land where sufficient water and suitable soil were available for rice production, although still in relatively close proximity to the household.

> "This area is used for paddy as it got water from another stream and from an overflowing lambo (small pond)." (Transect walk, Mwalo)

In all sites, rice cultivation has expanded rapidly since its first adoption, with the emphasis on cultivation shifting from subsistence to commercial production in recent decades. Asset ownership and control was not observed to greatly affect the adoption of the *majaluba* system at household level. Adoption of the RWH technique was almost universal across households at each site. The majority of households at each site were said to own fields in the *majaluba* areas or were renting them if they did not. The arrival and spread of the ox-plow was said to be an important factor driving the expansion of *majaluba* in the mid-twentieth century across all sites investigated as it became quicker and easier to prepare the fields using ox-plow.

Declining yields from staple food crops, particularly sorghum and millet, also appears to have driven farmers to expand their cultivation of rice:

> "[In the past,] we had a lot of food from sorghum and millet and so not much need to grow paddy." (Key informant, Mwalo)

In contrast to sorghum and millet, the use of *majaluba* allowed farmers to make use of rainfall outside of their immediate location, which reduced water-related crop losses:

> "Paddy brings in a lot of harvest, 3-5 times sorghum… We adopted it as we cannot depend on the rains and the upland crops but the gully brings in water from Kondoa, therefore [good] yield and production is more assured [in paddy fields]." (Men's Focus Group, Lionii)

Good markets for rice enabled farmers to turn previously unprofitable land into highly profitable paddy fields. Farmers reported that it is due to the relatively high selling price of rice that it has become the main cash crop for most households in their regions in recent decades. Poor market performance of sorghum and cotton, which were previously the main cash crops for these households, was reported to have fueled further the expansion of rice.

> "[We] changed from sorghum as it has no market value and we do not like the taste of it. We are not cultivating cotton much anymore as it is expensive to produce and has no market value… Cotton production started to reduce from [the year] 2011, as then was when

> its price decreased. We cultivate other crops where we used to cultivate cotton … Cotton used to be the main cash crop before rice."(Men's Focus Group, Lali)

> "[Rice cultivation expanded] because of business growth. We use rice as a cash crop instead of cotton [because] the price of cotton dropped and the market is not stable." (Men's Focus Group, Mwalo)

> "Before rice, sorghum and cassava were the main crops. Cotton has gone down in price so few people cultivate it." (Transect walk participant, Lali)

Aside from markets, social attitudes have also encouraged the expansion of rice cultivation. An increasingly favorable attitude toward rice led to increased adoption, as people's eating preferences turned from sorghum toward rice. This was thought to be due to the perception that eating rice represented a higher level of social standing, which reflected changes in eating habits in other areas of the country.

Information from the respondents indicated that external intervention has been minimal, with adoption spreading spontaneously through autonomous diffusion of knowledge from farmer to farmer. After learning the basics of rice cultivation from Asian migrant workers in Mwalogwabagore and Lali, farmers indicated that agricultural extension officers provided their main source of knowledge and support. Extension staff were said by farmers and key informants to have provided training and advised them on a range of agronomic practices, including changing from broadcasting to transplanting and leveling fields, for example. However, many farmers also said they 'found out for themselves,' which suggests that a process of trial and error may have also had a role to play. No specific projects or interventions relating to *majaluba* were conducted in any of the case study villages, but some farmers spoke of activities conducted in nearby areas that they saw or worked on.

In Lali, some selected farmers had traveled for training on rice cultivation and *majaluba* given as part of regional and national initiatives. For example, one key informant mentioned three farmers from Lali and two other hamlets in the area received two sessions of training at the Kilimanjaro Agricultural Training Centre in the late 1990s and early 2000s. The purpose was for these individuals to act as 'champion farmers' and share their knowledge with others upon their return. On the whole, evidence from focus group discussions suggested that in most cases this did not happen, although one farmer is said to have formed a working group of approximately five farmers to allow him to share the knowledge he obtained.

Although not direct recipients of external intervention, farmers in Lionii were able to use knowledge from projects implemented in neighboring settlements to both adopt and improve the *majaluba*. A later FAO project in neighboring Bahi-Sokoni was said to have been used as the basis for organizing the *majaluba* system in Lionii:

> "In Mashamba Mapia [area] there are good yields as this is the area with new fields where the layout was made with assistance from FAO, they drew a sketch plan of how fields and canals should be laid out in Bahi-Sokoni and we used this in Lionii [too]." (Key Informant, Lionii)

In contrast to the other two case study sites, farmers in Lionii spoke of the lack of support provided by agricultural extension staff in their hamlet, both for rice cultivation and other crop production activities.

Livelihoods and paddy cultivation

Not only do *majaluba* provide a way for farmers to benefit from rainfall runoff, they also provide flexibility and hence reduce farming (and therefore livelihood) risks. Farmers in Mwalogwabagore and Lionii spoke of the variation that occurred in area of paddy cultivated depending on farmers' perceptions of rainfall that would be received in a given year.

> "Once it starts raining we prepare the rice fields. There was not enough rainfall last year so not all paddy fields were cultivated…. areas cultivated were those with water, this water came from the dam in another village that overflowed. Those that did not cultivate did not get water from this. The area cultivated [in the paddy] depends on the rainfall each year." (Transect walk participant, Mwalo)

Data suggest that one of the reasons that *majaluba* have been so successful in the case study region is that the system is complementary to existing livelihood practices. *Majaluba* were said to be prepared in the month of October–November, after seeds for other staple crops, including maize, cassava, and millet, had been sown. See cropping calendar (Fig. 5).

However, the benefits of *majaluba* were not equally distributed among households. Access to and control over land and water was not equal across all *majaluba*. In general, those farmers who were closest to water sources, in the upslope areas of the lowlands, had better access and control. Downstream farmers were said to only have access once those upstream had finished irrigating their fields, in many cases relying solely on overflows from fields above. The lack of governance arrangements was said to lead to conflicts between upstream and downstream farmers in all sites. In Mwalogwabagore, there were reports during the transect walk and focus groups that some farmers with downstream *majaluba* sometimes made the decision not to cultivate in a particular year if the rainfall was not considered favorable, as the risk of insufficient water to meet crop demand was too high.

Rice is seen as both a food and cash crop by farmers. In most cases, the data indicate that use of *majaluba* has provided an additional source of food for households, both directly and indirectly. A proportion of rice (typically 30%) is reserved for household consumption, which is usually a different variety from the rice that is destined for sale (this is because farmers do not find the rice that reaches the highest price in market to be palatable). The outcomes of a ranking exercise conducted during focus groups in all case study sites suggest that rice provides a greater contribution to household food provisioning in Lali and Lionii compared to Mwalogwabagore, with rice ranked first/second and fourth most eaten crop, respectively. When sold, profits from rice were also used to purchase additional food crops, particularly maize, which is said by farmers to be increasingly difficult to cultivate due to changes in rainfall. It is not clear what overall impact the rice has had on food security levels across households, but in general it seems that

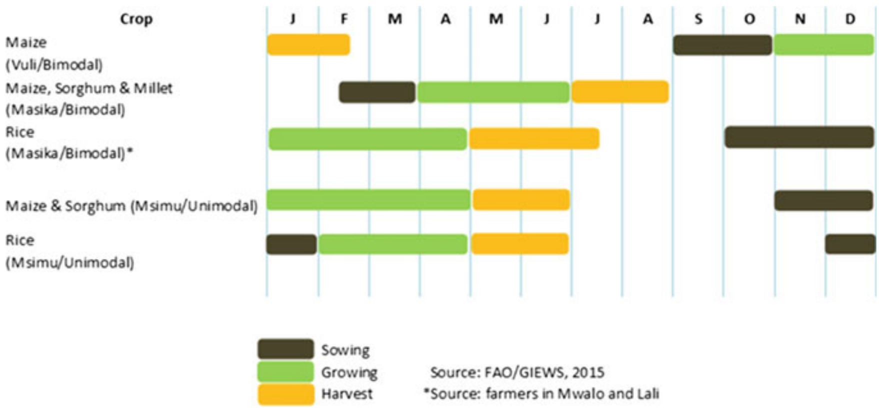

Fig. 5 Typical calendar for staple crops in Tanzania for regions with bimodal rainfall (Mwalogwabagore and Lali) and uni-modal rainfall (Lionii)

households are still not food secure. Aspects such as poor management of harvest and low rainfall still lead to food insecurity in some years:

> "They reduce the amount of crop buyers to stop people selling so much food." (Key Informant, Mwalo)

It is not clear to what extent the adoption of paddy cultivation using *majaluba* has offset reductions in yields from traditional food crops, including maize and sorghum. The *majaluba* system was said to help ensure good yields despite unreliable rainfall through the harvest of runoff from surrounding land or ephemeral streams and storing it within bunds. Yields in fields where farmers were harvesting and storing water were said to be higher compared to fields where they were relying on direct rainfall only.

Paddy provides a valuable contribution to household incomes across the case study sites. It was said to be the main cash crop in Mwalogwabagore and Lionii and second largest cash crop (after cotton) in Lali. Aside from the purchase of food, income from the sale of paddy is also used to meet wider household needs, such as education and healthcare costs. However, at the individual level, paddy provided a much greater contribution to men's income compared to women's, who relied more on the cultivation of horticultural crops and other non-agricultural activities for their income. Daily labor on other farmers' paddy fields provided a source of income for both men and women in some (poorer) households. However, regardless of large areas of paddy production and significant contribution to income it provided, households continued to be engaged in a range of other on- and off-farm agricultural activities, including non-farm casual labor and masonry for men, and charcoal preparation and sale of firewood for women.

Although data suggest that one of the reasons that *majaluba* have been so successful in the case study region is that the system does not conflict with existing livelihood practices, there was some evidence to suggest that households where livestock comprised a greater proportion of income than agriculture were negatively impacted by the expansion of *majaluba*, particularly in Lionii. This impact is largely due to the transformation of land that was previously used for grazing into paddy:

> "All of this area [now cultivated] was used for grazing before it was paddy fields. Now the grazing area used is 6 km away." (Transect walk, Lionii)

> "In the past many had livestock, but the grazing land has become scarce so these people decided to move away." (Key Informant, Lionii)

The future for *majaluba* RWH system

Farmers were found to be continuing to cultivate paddy and to look for areas to expand rice production further. In all study sites, the only constraint to the adoption and expansion of the *majaluba* system by farmers appeared to be a lack of appropriate land or ability to rent it. In Lali, fields that were previously used to cultivate maize, cotton, groundnuts were now being converted to paddy fields:

> "Rice cultivation started in the area along the railway as this is mbuga [clay] soil and it has access of runoff from the railway. Before we grew sorghum here and the same in the other fields [now used for paddy]." (Focus Group, Lali)

The reason for this change in crop was said to be due to low yields from sorghum and maize production in these areas, which suggests that *majaluba* provide an effective way for farmers to cope with changing rainfall in the region:

> "Paddy has expanded over the years, before paddy [farmers here] grew sorghum and maize [in these fields], but if they did not get a yield from one of these, they thought then, why not try paddy?" (Key Informant, Lali)

In general, there was said to be a growing scarcity of suitable land and farmers had limited possibilities for further expansion of paddy in their own villages/hamlets. Farmers were found to be renting additional land in neighboring hamlets and villages to enable expansion of production. In some cases, farmers were able to rent or purchase areas that were highly suitable for paddy production, but in some cases land scarcity led farmers to cultivate in less-suitable areas:

> "Some farmers are trying to expand [paddy], but into the wrong type of soil and so they have a high seepage and water loss problems." (Transect walk, Lali)

Farmers felt that soil infertility (due to lack of manure and fertilizer) was also responsible for limiting yields obtained in some areas, although in fields recently brought into cultivation this was not often an issue. According to key informants, lack of knowledge on optimal agronomic practices also limited yields for many farmers. This could be exemplified by farmers practicing agro-pastoralism, yet not carrying animal manure to their fields.

Focus group discussions indicated that access to and control over runoff was a key factor determining yields and would remain so into the future. Those with good access to runoff from gullies or surrounding land obtained higher yields than those located further away from runoff sources, or relying on direct rainfall only. There was a high level of competition to secure access to a field with a good runoff source, and not all farmers had the financial capital to rent fields considered to receive higher levels of runoff.

4 Discussion: Does the '*Majaluba*' System of Rice Production in Tanzania Represent a RWH 'Bright Spot'?

Based on recent investigations in seven countries in SSA, Critchley and Gowing (2012, p. 190–191) concluded that 'bright spots' are evident where RWH technologies have been successfully adopted at scale; however, data collection on their extent and impact continues to be inadequate. This analysis of the situation in Tanzania, based on the transect survey together with secondary data, indicates that the contribution of the *majaluba* RWH system to the growth of rice production in Tanzania is clearly very considerable, but available data do not reflect this reality. The RWH data problem is once again evident.

National data for rice production in Tanzania are not disaggregated by agroecological system and do not differentiate RWH systems. However, survey-based approaches (Diagne et al. 2013; Balasubramanian et al. 2007) have consistently demonstrated that the lowland rainfed production system represents around 70% of the total paddy production area. Not all is under *majaluba*, but survey evidence for Shinyanga Region (Nakano and Kajisa 2013) shows that this RWH system dominates there with 95% of rainfed paddy fields recorded as being bunded. Results of our transect survey through the central corridor confirm that lowland rainfed production is largely synonymous with adoption of the *majaluba* RWH system. A plausible estimate for the current total extent of the *majaluba* system in Tanzania is therefore around 500,000 ha from the central corridor alone and perhaps 600,000 ha across the whole country.

The results from this case study in Tanzania raise questions about transferability of the experience and the potential of mesoscale RWH techniques for sustainable intensification of agriculture more widely in SSA. What can be concluded about the drivers of adoption? Successful adoption of soil and water conservation measures in SSA drylands has been attributed to: household and farm characteristics, knowledge of technical innovations and external assistance, characteristics of the measures (labor demand, tangible benefits, etc.), stakeholders' perceptions, and impetus for diversification of farmers' incomes (Sietz and van Dijk 2015).

Evidence from the transect survey confirms the attractiveness of the *majaluba* rice system compared to alternatives available to smallholder rainfed farmers, as also reported by Hatibu et al. (2006) from a survey in Maswa District (Sukumaland). They reported a survey of 120 farmers using recall data for a period of six years and showed that the *majaluba* rice system performed best. Productivity of land was US$400–600 per hectare, and productivity of labor was US$10.5–12 per person-day. Follow-up monitoring of 90 farmers for two years confirmed this performance estimate with paddy yields recorded at around 4000 kg/ha. Plausible estimates therefore suggest that average yield for *majaluba* is around 2500 kg/ha, which might drop to 1500 kg/ha in a poor rainfall year and might increase to 4000 kg/ha in a good year as reported by Meertens et al. (1999).

It is clear that physical environmental characteristics may also influence performance and therefore successful adoption. Suitability depends on the following: rainfall, slope, soil type, soil depth (Bulcock and Jewitt 2013). It is tempting to propose that the success of the *majaluba* system is attributable to favorable landscape and soil conditions (e.g., hard-pan soils), but the extent of its range across the central plateau of Tanzania and reaching at least 1000 km from its origin indicates that it is suitable for a range of environmental conditions.

The transect survey has shown that farmers view rice as a dual-purpose crop with part (typically 30%) retained and consumed in the household and the remainder providing cash income. Not only does the *majaluba* RWH system provide a way for farmers to benefit from rainfall runoff, but it also reduces farming (and therefore livelihood) risks. It adds to household resilience in that its adoption does not conflict with existing livelihood practices and the choice of either retaining for household consumption or selling for cash provides livelihood flexibility.

Across SSA, the large majority of farmers do not have access to irrigation and in the future the great majority of farm families will continue to rely on rainfed agriculture for their livelihoods. Recent analysis (Ward et al. 2016) indicates that in only nine countries can irrigation be developed for more than 20% of the dryland cropped area (27% in Tanzania). The challenge of meeting future food security will depend on improving rainfed production through adoption of RWH (Rockstrom and Falkenmark 2015). The evidence reported here for a RWH 'bright spot' is important in this context, not least because the *majaluba* system has spread through autonomous diffusion of knowledge from farmer to farmer with minimal external support. Rice production is a focus for the Government of Tanzania on its 'Big Results Now' (BRN) initiative, but it is notable that the role of RWH is not mentioned and the focus is entirely on irrigated rice production (GoT 2015). There is a strong case for BRN to recognize the RWH 'bright spot' and build on its success.

5 Conclusions

An analysis of the available secondary data supported by a 600-km transect survey across the dominant rice production zone in Tanzania has demonstrated the importance of the lowland rainfed production system and the preeminence of the 'majaluba' RWH system. This system comprises a network of roughly level basins each surrounded by an earth bund and arranged in the landscape to collect local runoff from stony outcrops and grazing lands in upslope areas with cattle tracks often used as conduits. We estimate that the ‘majaluba’ system contributes about 60% of total rice production in Tanzania.

It is clear from the transect survey that the influence of external assistance has been minimal and the continuing expansion over eight decades and over a vast distance has been driven by autonomous diffusion of knowledge from farmer to farmer since its introduction in the 1930s. Rice production is not a traditional farming practice in Tanzania, but transfer of knowledge has not been a constraint to its adoption by 200,000–300,000 users. It is an appropriate technology that has allowed farmers to respond to opportunities provided by (i) the availability of the ox-plow which reduced the labor constraint on developing new land and (ii) the expanding market within Tanzania for rice which provided an attractive substitute for other cash crops while also allowing for household consumption as a staple food crop.

The *majaluba* system is an example of intermediate-scale external catchment runoff harvesting. This brings the advantage that fields can be developed by individual farmers who nevertheless still gain from runoff generated from a wider area of land. However, the ease of individual adoption and absence of formal water-user organizations may be seen as a constraint on sustainability. It can be seen that conflict between farmers over access to scarce water does occur. There is a case for external intervention to strengthen governance arrangements.

Nevertheless, the success of the *majaluba* water harvesting system in Tanzania is remarkable. It clearly represents an example of a successful agricultural innovation and is without doubt a water harvesting ‘bright spot’ with potential for transfer to other parts of SSA.

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