Floodplains in Mozambique: The Scope for Shallow Well Development

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Overview Paper Spate Irrigation

Spate Irrigation Network Foundation

1. Introduction

This paper shows the results of an exploratory study on the introduction of flood wells for smallholder irrigation in Mozambique. Flood wells are an innovative concept to provide floodplain farmers with access to water. Unlike hand-dug wells the proposed manually drilled tube wells are not damaged by floods and could be used for dry-season irrigation by engine or treadle pumps. While currently production is limited to rain-fed crops, the introduction of such technologies could allow farmers to grow two extra cycles of cash crops and increase their income drastically. In this way flood wells form a potential package to address the need for improved irrigation technologies in Mozambican floodplains as expressed by CPWF (2010).

The study commences by a mapping and literature study to get an overview of the Mozambican floodplains (chapter 2) and assess the technical and socio-economic feasibility of manual drilling for smallholder irrigation purposes (chapter 3). Based on this analysis three high potential floodplains have been selected for a field assessment, carried out in December 2014 (chapter 4). An overview of the scope for flood wells in different areas is provided in chapter 5, as well a strategy for its introduction.

1. *Figure 1 Hydrological map* (CENACARTA, 1997)

2. Floodplain overview

Mozambique has a large number of river basins which drain from the central African highland plateau into the Indian Ocean. Its major rivers are the centrally located Zambezi, contributing to 66% of the country's surface water; the Limpopo in the south, Rovuma in the north and Save in the centre. The rivers are fed by a much larger amount of small seasonal streams with torrential flow characteristics (see figure 1).

The country is located at the downstream end of the river basins, which is a vulnerable position from being extremely dependent on incoming flows in terms of quantity and quality. High flow rates during the wet season (December till March) cause abundant annual flooding, whereas dried streams and fields pose troubles to farmers in the late dry season (August to October).

Figure 2 indicates in green where the main floodplains in Mozambique are located; i.e. mostly along the coast and in the Zambezi and Limpopo basins. A distinction should be made between riverine, lacustrine and estuarine floodplains. Riverine floodplains are generally characterised by fertile alluvial soils of various types, including sand, clay and gravel layers.

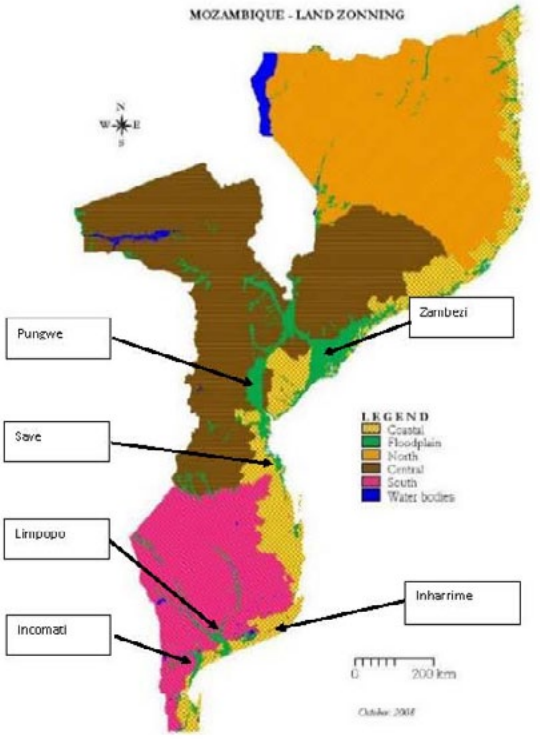

Figure 2 Floodplains in Mozambique (iDE, 2008)

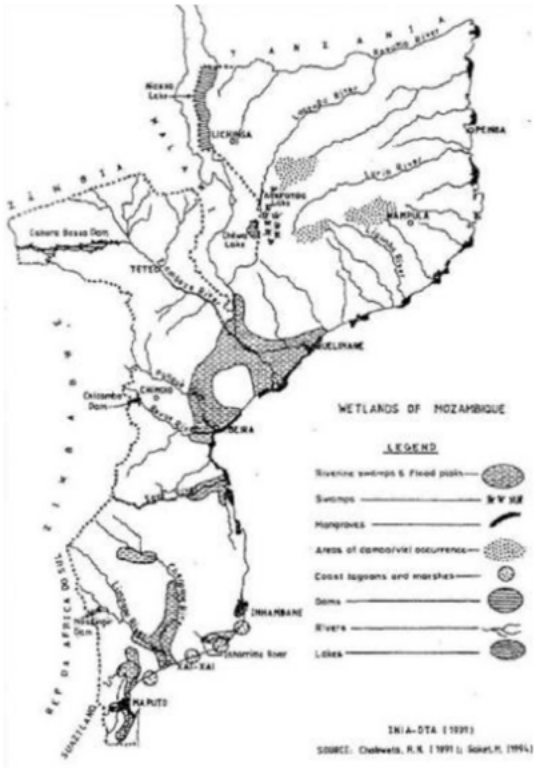

Figure 3 Distribution of wetlands (FAO, 2000)

A pilot study in Ethiopia has demonstrated that lacustrine floodplains on the other hand are featured by deep clay soils, which is a major constraint for the use of shallow flood wells (PRACTICA, 2014)[1].

Alternatively, estuarine aquifers are subject to saltwater intrusion, which leads to salinization problems when used for irrigation. Swamps and dambos, such as in the northern provinces, are often included in floodplain maps as well. However, due to respectively the salt content and abundance of surface water throughout the year, the scope for flood wells in those areas is limited. Hence, riverine floodplains are considered as the most suitable areas for shallow groundwater development for smallholder irrigators.

The distribution of wetlands from various natures is pointed out in figure 3. Combining figure 2 and 3 indicates that all major floodplains in Mozambique have a riverine character, except from the mangroves and lagoons at the coast and the swamps bordering Malawi. The feasibility mapping in chapter 3 will focus on those riverine floodplains.

3. Feasibility mapping for manual drilling

This chapter assesses the feasibility for manual drilling of the identified floodplains in Mozambique. The analysis encompasses both the hydro-geological and socio-economical suitability, in order to identify the areas where shallow groundwater development could have most impact.

3.1 Hydro-geological suitability

Manual drilling is a practical and affordable solution to get access to shallow groundwater. However, there are a number of hydro-geological factors to take into account. Technically manual drilling could go up to 40 meters depth in both alluvial soils (loose material, such as clay and sand) and soft weathered rock formations (such as soft sand stone and lime stone). To introduce wells that are affordable for smallholder farmers however, it is recommended to keep costs low by focusing on areas with shallow aquifers (within 20m) and an absence of consolidated materials.

Figure 4 Hydro-geology of Mozambique (DNA, 1987)

1) More detailed explanations on the geo-hydrological aptitude for flood wells can be found in chapter 3.1.

The hydrogeological map of Mozambique (figure 4) differentiates three main areas:

1) The basement complex, covering the major part of North and central Mozambique. These zones are characterised by ancient rock formations close to the surface and discontinuous aquifers.
2) The volcanic terrains, small zones in central Mozambique with only minor and dispersed aquifers.
3) The sedimentary basins, covering the whole South of the country (7) and the Zambezi (3 and 6), Mantamba (4) and Rovuma (5) basins, consisting of quaternary alluvium and mainly unconsolidated formations. Especially in the South, the unconfined aquifer is extensive and continuous, receiving considerable recharge by direct infiltration of rainwater.

Perforation by manual drilling is only possible in the sedimentary basins. However, not all alluvial zones are suitable for tube wells. Especially for irrigation purposes it is required to tap from highly productive aquifers. Such aquifers consist of permeable soils like sand and gravel. On the contrary, water extraction from impermeable clayey soils is only possible through large diameter wells.

Figure 5 indicates in blue where the high potential intergranular aquifers are situated. Figure 6 shows that those zones correspond to the areas characterised with a lithology of unconsolidated sand and gravel (shown in light yellow). The presence of such permeable layers was confirmed by drilling tests in Caia district (PRACTICA, 2013). Those are the areas with a technically sound potential for manually drilled tube wells, which will be the focus areas for the socio-economic analysis.

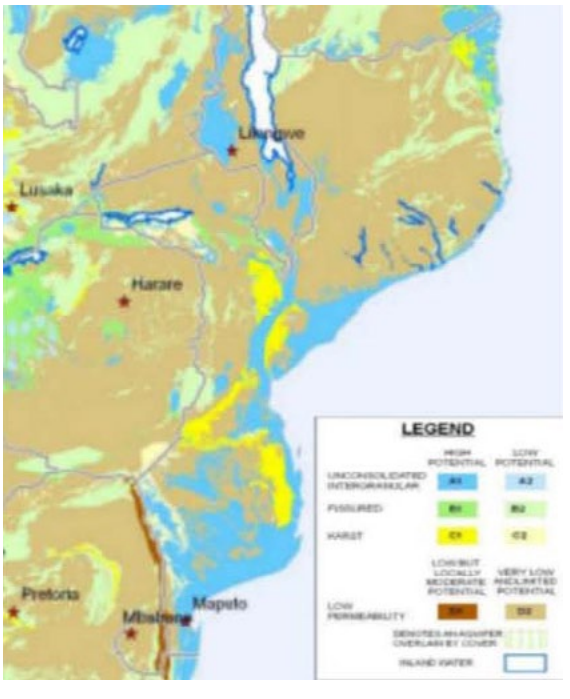

Figure 5 Aquifer potential (SADC, 2009)

3.2 Socio-economical suitability

Technical feasibility alone does not mean that there is a scope for a particular technology. Therefore the study includes a socio-economic analysis to select those areas where flood wells could contribute most. The technology aims to increase the productivity of smallholder farms. The potential to realise this objective is most pronounced for farmers with experience on irrigated production, but a lack of sufficient water resources. Communities with livelihood strategies based on fishing, livestock, or rain-fed production only are less likely to directly benefit from flood wells and adopt this technology.

Although flood wells have a relatively low-cost, for a smallholder farmer it is still a considerable investment that needs to pay off. Therefore the presence of nearby markets is indispensable. Furthermore, there is only scope for a viable well drilling business in a starting hub with sufficient potential customers. Hence, the main socio-economic factors taken into account are the type of farming systems, local demographic features and vicinity or access to major towns.

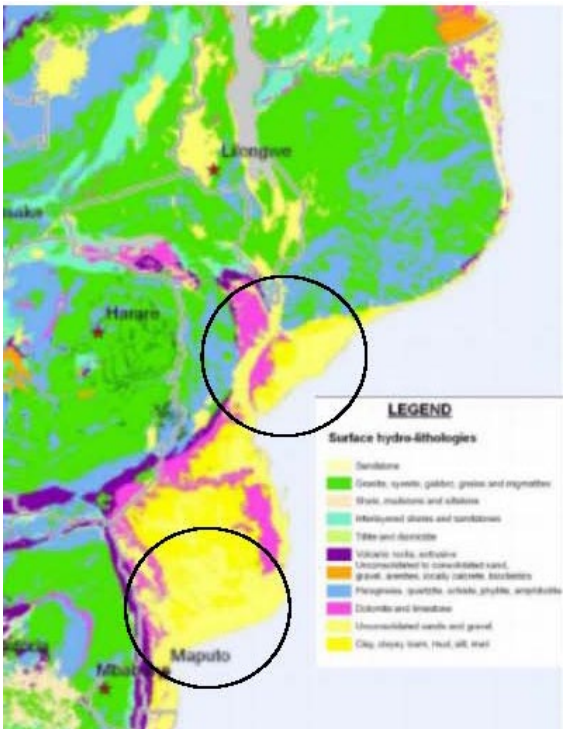

Figure 6 Surface hydro-lithology In circles the focus areas for further assessment (SADC, 2009)

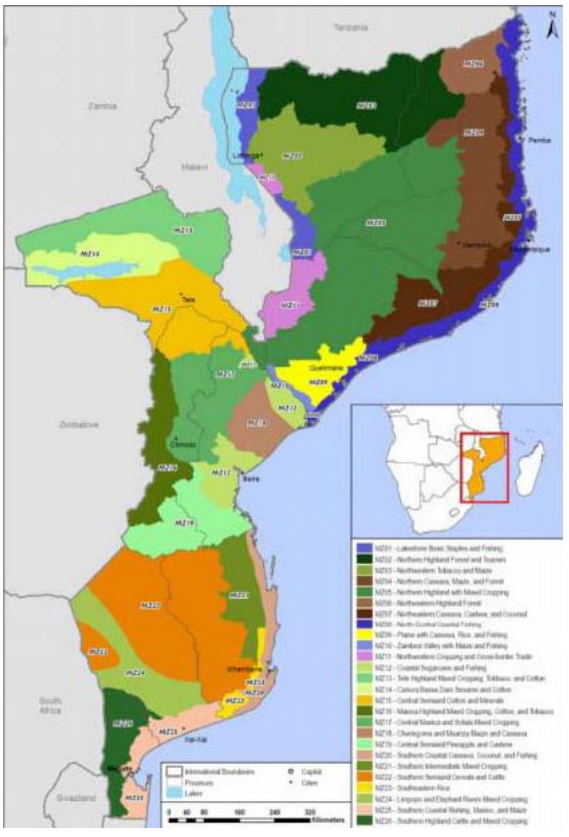

Figure 7 Livelihood zones (FEWS NET, 2014)

The selection of target areas preceding the field analysis was mainly informed by an extensive livelihood mapping study executed by FEWS NET (2014). The resulting zoning (see figure 7) is based on different agricultural typologies, food security, demography and access to water. The study showed a promising scope in the lower Zambezi, lower Limpopo and Inharime plains (figure 8). More detailed socio-economic data on those areas will follow in chapter 4, showing a close-up of high potential areas. The Pungwe River going to Beira was the only major flood basin discarded, due to its low population density and the inaccessibility of markets (FEWS NET, 2014; INE, 2007).

3.3 Selection of target areas

The mapping and literature study described above have identified the lower Zambezi, Limpopo and Inharime plains as high potential areas for flood wells. Chapter 4 zooms in to those three areas and shows the outcome of the executed field assessment.

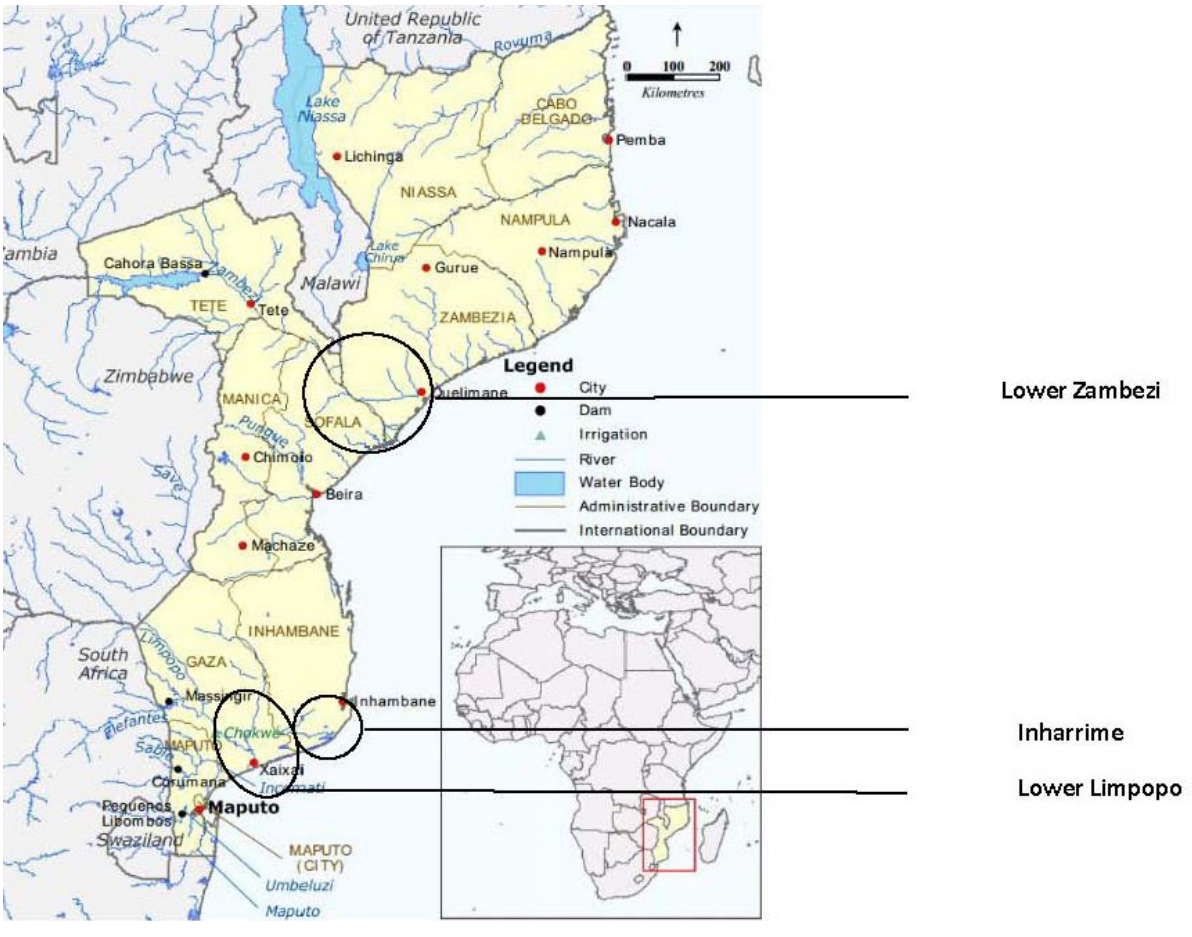

Figure 8 Location of target areas for field assessment

4. Close-up of target floodplains

4.1 Zambezi delta

The Zambezi is the fourth-longest river in Africa and the largest river of Mozambique. The area of the basin is 1.390.000 m^2, shared by eight countries. From its origin in Zambia it passes 2,574 km until draining into the Indian Ocean. Its massive floodplains have an immense value as one of the most productive and biologically diverse floodplains in Africa. More than 32 million people rely on the river for drinking water, agriculture as well fisheries (IFCR, 2010). In Figure 9, remote sensing images (earth observatory, NASA) from December and February show the enormous growth of the river during the rainy season. The images were made with both infrared and visible light to provide greater contrast between water and land. Field research confirmed the different livelihood realities as mapped by FEWS Net (2014). Four zones have been identified, i.e. the riverine zone, Sofala plains, Zambezia plains and the coastal zone (see figure 9).

Riverine Zone
The riverine zone covers a relatively narrow stroke along the main river course, corresponding to zone MZ10 in figure 7. People's lives are centred around the river and flooding patterns are incorporated into the spatial and temporal arrangement of their farming activities. The area has a moderate to high population density of 12 – 33 persons/km^2. Around Caia there is good market access with traders from Nicoadala and Qualimane. Labour is widely available, but the supply of agricultural inputs is irregular.

The riverine zone is characterised by very fertile loamy and sandy soils that are very suitable for agriculture. The average land holding is about 1-2 hectares per household, most of it used for subsistence farming of rain-fed crops (maize, sorghum, rice, and around dambos some cassava and sweet potato) and livestock rearing. Some people irrigate small vegetable plots by hand, using water from the river or from 0-2 m deep dug wells. Around Mopeia, irrigated plots are actually located within the riverbed, posing risks related to early flooding and attacks by crocodiles.

The government aims to displace people to higher zones, but farmers refuse due to a lack of water. Production in the major part of the floodplain is limited to one cycle of rain-fed crops, and horticultural production is concentrated along the river and ponds. There is a very good scope for pumps and wells, which could increase productivity drastically.

Sofala plains
The Sofala plains cover the southern side of the main river course and corresponds to the MZ12 zone in figure 7. The low-lying area with shallow water tables is very suitable for sugarcane production, which is grown on large-scale plantations. People rely on income from this sector, as well as on fishing, aid and subsistence farming. Access to markets is difficult due to poor road conditions and the large distance to town. Government officials indicated that people's mind-sets are not focused on production for sales, which is also shown by the limited trade among local villages. Hence, the remote circumstances and resulting focus on subsistence activities require more support than just the introduction of water technologies.

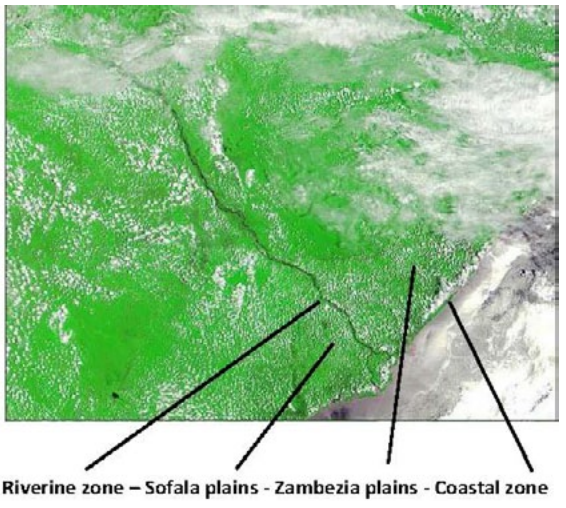

Figure 9 Remote sensing images taken in December (left) and February (right) showing the floodplains in the Zambezi delta. (NASA, 2001)Different livelihood zones and the locations of field research are indicated as well.

Zambezia plains
The Zambezia plains in this study refer to the major floodable zone North of the Zambezi river, indicated by category MZ09 in figure 7. The area is densely populated with 32 – 90 people / km^2 and market access by road to Nicoadala and Qualimane is good. Soil conditions and farming practices are comparable to those in the riverine zone described above. The area knows some smallholder irrigation and sales of surplus crops. The volumes are limited however, as the common field size amounts to 1/8 ha. According to local government officials, access to water would increase production and allow farmers to produce off-season (September – December), generating a higher price for their products.

Coastal zone
A narrow stroke stretching along the coast indicated by MZ08 in figure 7. The area is densely populated and has good market access, however the main income sources are tourism and fishing rather than agriculture. Therefore, this zone is not considered as a high potential area for flood wells.

4.2 Limpopo delta

The Limpopo river flows over 750 km from South Africa to Mozambique and drains into the Indian Ocean at Xai Xai. Its total basin counts approximately 408.000 km^2, with around 1.3 million people living in the Mozambican part (LBPTC, 2010). The upper Limpopo in Mozambique is almost inhabited, so the study focuses on its delta. Figure 10 shows the areas assessed.

Chokwe district
Chokwe district is located at the Southern side of the Limpopo River. It is mainly characterised by commercial farms and large cannel irrigation systems receiving water from a storage reservoir. Since this provides a limited scope for flood wells, no further field assessment has been executed.

Guijá district
Guijá is located just North of Chokwe at the other side of the Limpopo river. Contrary to Chokwe, this area is featured by smallholder farming systems growing predominantly maize and beans in the floodplains. The field assessment showed that land along the river is cultivated by farmer associations, using engine pumps to withdraw water from the river. The individual plots are situated farther away from the river, and as a result only used for rain-fed crop production. A major income source is provided by temporary work in South African gold mines. Physical access to markets is relatively good, as both the towns Chokwe and Xai Xai are easily accessible. Soil observations showed both sand and clay, but no information about soil profiles > 2m could be retrieved. More data on groundwater levels are needed as well, as its depth varies with respect to the distance from the river. In short, the area shows potential for irrigation development through flood wells, as there is know-how on irrigation and some incoming financial resources to invest. Compared to the Zambezi basin however, the size of the floodplains is limited.

Xai Xai district
Contrary to the remoteness of the Zambezi estuary, the river Limpopo leads to the Ocean in the highly populated Xai Xai district. Its coastal zone is of great interest to Chinese investors and some large-scale surface irrigation schemes have been developed. Surface water is abundant whereas shallow aquifers could cope with salinity problems (Owen and Madari, 2009). Hence, the coastal zone is not showing a good scope for flood wells.

The upper part of the district however, e.g. near Chicumbane, is mainly cultivated by smallholder farmers.

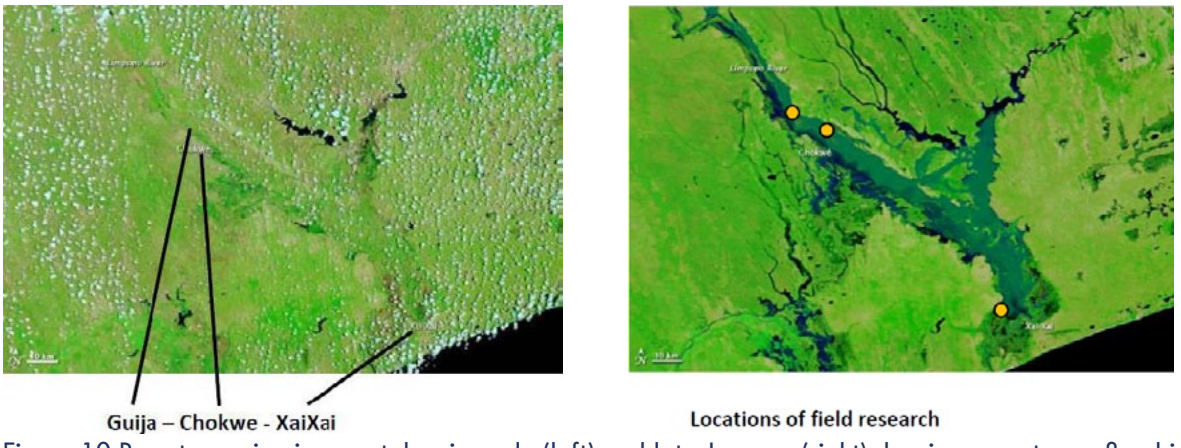

Figure 10 Remote sensing images taken in early (left) and late January (right) showing an extreme flood in 2013 (NASA, 2013). Different livelihood zones and the locations of field research are indicated as well.

Figure 11 Water abundant irrigated field in Inharrime

They are used to grow rain-fed crops and a first cycle of horticultural crops in the cold season on residual ground moisture or low-laying peat soils. Growing an irrigated second cycle is done rarely as engine pumps frequently break down and there is a lack of technical capacity for its maintenance. Markets are very well developed and includes a state-subsidised supply of seeds. Because of its favourable market access and abundant surface and shallow groundwater in the low plains, a reliable pump supply chain would make a major impact on agricultural productivity. Tube wells could be a valuable addition, but have less scope if water could be easily accessed from small ponds as well.

4.3 Inharrime plains

The plains North from Inharrime are a smallholder horticultural production hub, based on fertile soils and abundant surface water. Irrigation of a large variety of crops is done manually and as a result not much products are left for sales. Market access is relatively poor as the fertile plains are not situated near any major road or town. Agricultural productivity in this zone could be increased by improving access to markets and pumping technologies. The abundant surface water provides no scope for flood wells.

5. Conclusion

5. 1 Potential for upscaling

Mozambique is a country with vast floodplains and its population is predominantly engaged in smallholder agriculture. This study based on literature research, mapping and a field assessment has shown a large potential for tube wells and low-cost pumps to increase the productivity in floodplains.

The major part of wetlands and floodplains in Mozambique concern riverine areas featured by abundant sedimentation of sand and gravel, which has shaped highly productive aquifers. The shallow aquifers and lack of consolidated materials provide a high feasibility for manual well drilling.

Socio-economically the scope for flood wells is highly variable, depending on the local farming systems, current access to water, common livelihood strategies and market access. A viable business in well drilling can only be established if sufficient farmers are willing to invest. This requires a context of market-oriented smallholder farmers that are constraint by limited water access.

The largest scope has been identified in the floodplains at the Northern side of the lower Zambezi River. Remote and coastal zones mostly showed a limited scope as the majority of its inhabitants are not focused on cash crop production. Table 1 provides an overview of the technical, socio-economic and overall potential for flood wells.

5.2 Target stakeholders

To unlock the potential of floodplain agriculture it is recommended to develop viable supply chains for small-scale irrigation pumps (treadle pumps, micro pump-sets) and manual well drilling. Supporting the capacities of local entrepreneurs creates know-how to provide sustainable sales and maintenance services on a local level. The observed high rates of pump failure showed that such services are indispensable for any successful introduction of technologies.

The Ministry of Agriculture (MINAG) is responsible for irrigation development in Mozambique. Traditionally the government has focused on large-scale irrigation schemes to feed the nation. Though this is still the main development model, the National Directorate for Agrarian Services

	Technical Suitability	Socio-economic Suitability	Potential for Flood Wells
Lower Zambezi			
Riverine zone	High	High	High
Sofala plains	High	Low	Low
Zambezia plains	High	High	High
Coastal zone	Medium	Low	Low
Lower Limpopo			
Chockwe	High	Low	Low
Guija	High	High	High
Xaixai	Medium	Medium	Medium
Inharrime			
Inharrime plains	High	Low	Low
Pungwe	High	Low	Low
Save	High	Medium	Medium
Incomati	High	High	High

Table 1 Potential for tube wells in different floodplains

(DNSA) now also supports the strengthening of smallholder irrigators by improving market access and providing technical support (MIPP, 2011). Governmental support to smallholder farmers is mainly organised on a district level and includes subsidised input provision, credit facilities and extension services.

To allow for farmer investments in water technologies it is crucial to combine the introduction of technologies with credit provision. Many districts manage loan supply through a District Development Fund (FDD). Financing pumps and/or wells complies with the objectives and requirements attached to this fund. A number of other credit providers exist (FDM, GAPI, CPL) but those funds are intended for agricultural inputs rather than equipment.

Governmental support is also found through regional agencies, such as the Agência do Zambeze which coordinates planning . This organisation has shown interest in manual well drilling for multiple purposes, including smallholder irrigation. The agency also supports farmers in the Zambezi delta with credit for engine pumps, coving 75% of the initial purchase price.

To implement a capacity building programme for flood wells it is recommended to involve a locally based NGO as well. The local branch of International Development Enterprises (iDE) is an interesting partner in particular, as it targets farmers within the promising Zambezi zones. The project partners are exploring ways to join forces with this organisation to upscale the identified floodplain development approaches.

Figure 12 River in the Sofala plains during the dry season

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Colofon

This note was prepared by Berry van den Pol, Robert Vuik and Lucía Sáenz Terrero and is part of the Tube Wells in Floodplains project.

The Tube Wells in Floodplains project, supported by Partners voor Water, aims to increase the productivity of marginally used floodplains by introducing a low-cost package of shallow tube well drilling techniques including pump technologies that can provide smallholder farmers with access to shallow groundwater.

The Spate Irrigation Network Foundation supports and promotes appropriate programmes and policies in flood based farming systems, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in Spate irrigation. For more information: www.spate-irrigation.org.

February 2015