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Co-creation of affordable and clean pumped irrigation for smallholders: Lessons from Nepal and Malawi

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Abstract
Pumped irrigation is a way to improve water control for smallholder farming, hence to intensify its production. In this context, the Dutch company aQysta has developed the Barsha pump (BP), the first-ever commercial version of a hydro-powered pump traditionally referred to as spiral pump. BPs, however, have to deal with several constraints that affect the decision-making and access of smallholders to this as well as other agricultural (water pumping) technologies, thus to their benefits. On this subject, Product Service System (PSS) is a type of business models able to potentially cope with a number of restrictions of different nature (i.e. technical, financial, social). Moreover, if co-created with the feedback of the users, and by addressing contextual tensions of different cases, these models can be substantially richer than their top-down counterparts. From this perspective, six cases of use of BPs have been addressed in Nepal and Malawi, respectively. Both primary and secondary data, which was analyzed qualitatively under the analytic induction approach, was collected through a number of methods: on-site observations, unstructured interviews, structured questionnaires, and Q-methodology. Evidence shows a wide range of (non-)technical facilitating and hampering conditions for the use of the BP, as well as preferences of the smallholders in regards to existing and proposed business model elements. Based on the corresponding analysis, a set of opportunities for an improved BP-based business model – PSS, aiming to fulfil several (and at times opposing) needs, is ultimately proposed in the current paper.

Keywords
Hydro-powered pump; Barsha pump; spiral pump; smallholder; business model; product-service system; co-creation

INTRODUCTION

Given the significant quantity of smallholder farms worldwide (Lowder et al., 2016), intensifying their crop production is key for food security, as well as in creating positive impacts in their livelihoods. Amongst many challenges that smallholders face, proper water management is one of the most critical elements to achieve such objective (Giordano et al., 2019). A way to improve (or enable) access to and control of irrigation water is—yet not limited to—by the use of pumping technologies to water lands that will remain otherwise (partly) unirrigated throughout the year.

Most water pumping systems, however, operate on electricity or fossil fuels, thus are (too) cost-intensive, or even inaccessible, for many smallholders due to the continuous use of electricity and fossil fuels (Chandel et al., 2015); moreover, they affect the environmental quality due to their gaseous emissions and noise. More environmentally sound and at times less expensive alternatives are renewable energy (RE)-based pumping technologies (Gopal et al., 2013). From these, hydro-powered pumping (HPP) technologies—i.e. those hydro-mechanically driven by the water they lift—pose even further advantages over their other RE counterparts (Fraenkel, 1986).

The Dutch start-up company aQysta developed the Barsha pump (BP), the first ever commercial version of a HPP device traditionally referred to as “spiral pump”, firstly reported during the 18th century (Ziegler, 1766) and applied after the late 70s in a number of countries (Morgan, 1984; Naegel, 1998; UNEP, 2015). Roughly 150 BP units have been deployed since 2014 in Nepal, and 13 units since 2018 in Malawi (aQysta, personal communication, July 26, 2019). The BP has to deal with market inefficiencies caused by, amongst others, underdeveloped supply chains, economic constraints, lack of knowledge, amongst others, which consequently limit the access of smallholders to this as well as other agricultural technologies, thus to their benefits (Giordano et al., 2019).

A business model that potentially can deal effectively with such a number of restrictions, while at the same time creating value for the involved parties, is ‘Product Service System’ (PSS) (Mont, 2002). In addittion, some authors state that a participatory process of co-creation / co-design (Dahan et al., 2010), especially while identifying and addressing contextual tensions at an early stage—in line with the so-called Context Variation by Design (CVD) approach (Kersten et al., 2017)—will substantially enrich the outputs to meet the user’s needs. However, with exception of few authors (Corti et al., 2013; Devisscher and Mont, 2008), these models have not been studied within the agricultural sector—let alone their co-created, bottom-up versions. None of them as well have addressed the specific case of water pumping technologies for smallholder farming.

In that perspective, Delft University of Technology and Comillas Pontifical University, are exploring the co-creation and implementation of affordable and clean pumped irrigation systems for smallholders, based upon novel HPP technologies like the aQysta BP (Intriago et al., 2018). Within this context, the objectives of this paper are: (1) to qualitatively analyze different (and opposed) use cases of BPs in Nepal and Malawi; (2) to highlight the underlying reasons for (not) using the BP, with emphasis on the most preferred / least preferred current and proposed BP business model elements (BME); and, (3) set grounds, based on the feedback of smallholders, for the future co-design of an improved BP-based PSS.

MATERIALS AND METHODS

Criteria for selection of use cases

The BP use-cases were selected within certain Nepali and Malawian smallholder communities, during the field visits in June – July 2019, based on the following criteria: (1) at least one BP must have been posing continuous presence for ≥ 2 months; (2) in accordance with the CVD approach, the BP use-cases must show different characteristics (e.g. topography, water source, facilitating / hampering conditions) between each other.

Data collection

Primary data, both quantitative and qualitative in nature, was collected and triangulated by: (1) direct on-site observations; (2) unstructured interviews to BP users, other smallholders (non BP users), and experts (authorities, NGOs) relevant to the chosen communities; (3) structured questionnaires administered to smallholders; and, (4) Q-methodology. Secondary data, which complemented the understanding of the researched phenomenon, was collected through: (1) databases administered by aQysta on the use of BPs; (2) official documents issued by the respective Nepali and Malawian authorities; and, (3) other related literature.

Data analysis

Due to their nature, as well as to the size of the selected population, the collected data will be analyzed qualitatively, under the analytic induction approach. Particular attention will be given to contrasting data between cases, in line with the aforementioned CVD approach.

RESULTS AND DISCUSSION

On the basis of the criteria pointed out above, the selected communities were, in Nepal: (1) Sokhu Besi neighborhood in the Jhangajholi Ratamata village, Sindhuli district, (2) Manthali municipality, Ramechhap district, and (3) Lele village, Lalitpur district; and, in Malawi: (4) Michiru, near Blantyre, (5) Tedzani, near Zalewa, and (6) Kachere cooperative, near Ntchisi. These BP use cases show a wide range of codified categories / attributes, as summarized in Table 1.

Brief description of cases

Case 1: Sokhu Besi. The farmer is the sole owner of the BP, obtained by means of a subsidy (~90%) from the local government. The water supplied by the BP supports both crop—mainly vegetables sold to local markets—and livestock farming. The unit has been operative yet with two broken waterwheel paddles, thus working less efficiently. The farmer counts on basic complementary infrastructure for pumped water management: two plastic reservoirs and one plastic-lined open-air excavated pond, both at farm-ground level. The BP shares space with other two community-owned diesel water pumps on the riverside. The latter require fuel input, resulting in operation costs 600 NPR (~ €4.80) per hour per farmer. Nevertheless, in general the community prefers the diesel pumps over the BP due to its higher pressure and flowrate, and (perceived) faster spinning speed.

Case 2: Manthali. The farmer has two BPs, one owned—subsidized ~90% by the government—and one lent quad-spiral prototype (intended to reach twice the pumped flow. His farm consists of several plots, some of them rented from neighboring farmers, to produce vegetables for sale at the local market. Albeit in operational conditions, none of the BPs was in use at the time of the field visit. The farmer argued this was due to the forthcoming rains, hence potential floods that could flush away the pumps; however, this might also be occurring due to the preferential use of groundwater sources within his lands. According to other interviewees, the farmer receives more revenues from selling groundwater to neighbors than the agricultural produce itself. This coincides with the fact that some plots remain barren, although he could ensure higher water volumes by additionally using the two BPs.

Case 3: Lele. The current farmers took over the farm on rental basis three months before the field visit. An infrastructure was already established, i.e. open plastic greenhouses and drip irrigation system, though the latter was removed by the farmer. The breast-shot BP lent along with the farm, stopped functioning after a flood damaged the ~0.50 m weir four months before. The farmers do not know how the BP operates. As a consequence, they bought an electric pump right away to supply their farm's need of water. This pump feeds an in-farm plastic-lined excavated reservoir, as well as a sprinkler irrigation system. They grow a number of vegetables that are sold locally.

Case 4: Michiru. This farm is a BP demonstration site in the Blantyre District. Since the farmer is aware of global warming effect, he sees the BP as an ideal technology. The unit has been in his possession for three months without any charge, after which he will have to start paying it off. The BP has been working so far irregularly due to water level fluctuations. Consequently river management—done through sandbags—will remain a reoccurring activity. The water supplied is used to irrigate several types of vegetables. Moreover, the farmer constructed a reservoir, which acts both as water storage and fish pond, to further manage the pumped water. After filling it, the water quickly seeped away; aQysta has offered to supply with a plastic lining to tackle this issue.

Table 1. Attributes of the selected BP use cases in farming communities in Nepal and Malawi.

	Nepal			Malawi		
	Sokhu Besi	**Manthali**	**Lele**	**Michiru**	**Tedzani**	**Kachere cooperative**
Distance from aQysta	88 km	129 km	16 km	3 km	60 km	396 km
Travelling time	~3.5 h	~5 h	~1 h	15 min	~2 h	~6.5 h
Topography	River bottom valley	River bottom valley	Sub-valley	River bottom valley	River bottom valley	Shire river basin
Accessibility	Next to national highway	Next to regional road	Next to district road	Next to district road	Next to footpath	Next to dirt road
Main water source	Sun Koshi river	Tamakoshi river	Unnamed river	Likhubula river	Shire river	Chafumbi river
Farm size	0.4 ha	1 ha	0.2 ha	~1 ha	4 ha (partly cultivated)	~1.5 ha
BP presence time	~3 y	~2 y	~1.5 y	~ 3 m	~ 2 m	~ 3 m
Facilitating conditions for BP	-Closeness to river (~170 m) -Stream speed	-Closeness to river (~80 m) -Stream speed	-Closeness to river (~105 m)	-Closeness to river (~30 m)	-Closeness to river (~80 m)	-Closeness to river (~120 m) -Stream speed
Hampering conditions for BP	-Presence of diesel water pumps	-Groundwater sources	-Stream speed -Need of a weir -River floods	-Stream speed -Changing water depth -Need of a weir	-Stream speed -Floating weed -Changing water depth	-Lack of irrigation equipment
BP ownership	-1 private	-1 private / -1 lent	-1 lent	-1 lent (demonstration)	-1 lent (for testing)	-1 private
BP conditions	Partially functional and operative	Fully functional yet not operative	Fully functional yet inoperative	Partially functional and operative	Partially functional and inoperative	Fully functional and operative
Farmer attitude on BP	Willing to keep using it	BP less useful than other water pumps	BP does not provide any benefit	Willing to keep using it	Willing to keep using it	Willing to keep using it
Impact of the BP	The farm relies on the BP	None (BPs not in use)	None (BPs not in use)	The farm relies on the BP	None (BP not in use)	The farm relies on the BP
Most preferred existing BME	-Subsidies -Clean energy	-Subsidies -Zero operation costs	-Clean energy -Easy to install and use -Subsidies	-Flexible payment methods -Zero operation costs -Clean energy -No human labor	-Flexible payment methods -Zero operation costs -Clean energy	-Flexible payment methods -Zero operation costs -No human labour
Most preferred proposed BME	-Extra services -Entrepreneurial training -Creation of jobs	-Extra services -Creation of jobs	-Nothing	-Extra services (reservoirs) -Provision of (basic) infrastructure	-Nothing	-Nothing
Least preferred existing BME	-Complex maintenance -Savings in operation -Pumped pressure	-Pumped pressure -Perceived saved labor	-Maintenance provided by an external organization	-Weight and size -Easy to steal/vandalism	-BP does not operate yet	-Pumped flow rate
Least preferred proposed BME	-Paying for extra services	-Non-ownership models -Entrepreneurial training -Paying for extra services	-Entrepreneurial training -Intervention of external organizations -Paying for extra services	N/A	N/A	N/A
Attitude of other farmers on the BP	-Not enough pumped pressure nor flowrate -Diesel water pumps are more useful	N/A	N/A	-Curiosity on the BP operation -Skeptical about BP efficiency, though they think the owner made a good decision	-Curiosity on the BP operation	N/A

Case 5: Tedzani. This farm is an experimental site, intended to test the BP feasibility in the Shire river. Its conditions however, are challenging: too deep to anchor the BP, too low water speed next to the banks, rapidly fluctuant water level, and houses crocodiles. If this pilot turns successful, the farmer will pay the BP off in instalments—a key driver for her choice—after which she is willing to buy another one. The main reason to adopt a BP was to cut down on fuel costs of the pumps that are currently used for irrigation. The BP was in the water but not operating due to low water speed.

Case 6: Kachere cooperative. This is a group of smallholders that has received support from several organizations; they shifted from watering cans to treadle pumps, and later on to diverting the river and gravity irrigation. None of these methods worked to their satisfaction, as such they inquired a BP, which was provided after paying a deposit. Yet, they find the pumped flow rate insufficient. This occurs due to the inadequate water management, associated with lack of infrastructure (e.g. sprinklers, reservoirs): water pumped through the night is not stored but simply flows off. Even though farmers are aware that they could pay in instalments, affordability is still a concern.

Facilitating and hampering conditions for the BP

It was observed, in line with findings on other HPP devices (Garman, 1986; Naegel, 1998; Weng, 1994), that a sound technical performance of the technology does not guarantee its sustained use. In Manthali and Lele, the BPs were simply neglected despite optimal working conditions. In Sokhu Besi and Kachere cooperative, similarly to other studies on RE-technologies (Bhattacharyya, 2006; UNCTAD, 2010), (in)existence of external elements (e.g. reservoirs, centrifugal pumps) affected the perceived usefulness of the BP. Within another Nepali community, the BP was deemed as undesirable since it might impede the provision of a subsidized diesel water pump (aQysta, personal communication, June 11, 2019). On the contrary, the Michiru and Tedzani cases depict the willingness of the farmers to use the BP, even though site conditions were unfavorable.

These conditions, particularly for newly adopted technologies, are negatively boosted by weak supply chains (Giordano et al., 2019; Johan, 2015; Weng, 1994). In both Nepal and Malawi, aQysta rely only on a centralized office; as a consequence, all the site-dependent after-sale services (e.g. reparation, maintenance) are decreased in efficiency (Dahan et al., 2010). In both countries, due to their topography and road conditions, extended travelling times deepen the remoteness of certain locations, thereby worsening the already limited logistic networks (UNDP, 2018).

Preferences on existing and proposed BME

Most preferred existing BME. Some existing BMEs could cause undesirable side effects if not well managed. Subsidies can steer practices and behaviors, hence to cope with several barriers (e.g. unaffordability, promotion of use, gender inequity) (Bista et al., 2018; Fisher and Kandiwa, 2014; Rai et al., 2019). Nevertheless, if not considered as temporary elements of change, linked to obligations from the counterpart, they can turn into permanent “crutches” for smallholders (Clay, 2013), even posing eventual decreases in productivity (Paudel and Rago, 2017). Moreover, the technology is prone to be deemed as a mere handout due to the lack of empowerment. In some cases, subsidies can be out of the reach of many smallholders, due to e.g. remoteness or institutional barriers (Gauchan and Shrestha, 2017; Paudel and Rago, 2017). Unlike Nepali BPs, which are largely subsidized by the local governments, the Malawian ones do not rely on such mechanisms (although they are previously half-paid by UNDP), hence their unaffordability is worsened in the latter. Therefore, flexible payment methods, e.g. instalments, is a preferred BME in Malawi. Although zero-operation costs and no human labor required are strengths of the BP, they could be misinterpreted as zero-maintenance due to a lack of understanding of the technology (K.C. et al., 2011). If proper maintenance is not given to the BP, its lifetime will be severely compromised.

Likewise many other newly introduced (RE) technologies, the BP was observed to require substantial follow-up support and maintenance assistance, as well as transfer of know-how (Gewali and Bhandari, 2005; Johnson and Lybecker, 2009). Despite being a clean energy-based technology, and notwithstanding its advantages, the BP faces some challenges that might hamper its implementation: policy barriers, lack of awareness, and financial barriers (K.C. et al., 2011).

Least preferred existing BME. In Sokhu Besi, where the BP was in operation within their applicability ranges, its pumped pressure and flowrate were considered insufficient. In Michiru, it was seen as a useful yet cumbersome device that could be stolen or vandalized. As pointed out by K.C. et al. (2011), this might be linked to a lack of awareness of the technology and its benefits. This was aggravated by the presence of other (traditional) water pumps; and, by the absence of safety means and water management infrastructure that reduces its usefulness, respectively. In the Nepali cases, despite the BP's virtual zero operation costs, its savings are not perceived as compensating the high upfront cost. Therefore, it becomes imperative to increase its affordability as well as the understandings of the farmers on the technology (K.C. et al., 2011). The maintenance of the BP, though not specialized, is seen as complex by the Sokhu Besi and Lele farmers. This might be increased by the lack of know-how that would enable local partners and/or owners to perform it (Johnson and Lybecker, 2009); i.e. even small repairs must be conducted by the company headquarters. In the Lele case, its maintenance by an external organization is deemed as undesired.

Most preferred proposed BME. Both extra services—e.g. assistance, infrastructure, inputs—and creation of new jobs, fit under a product-oriented PSS (Beuren et al., 2013; Mont, 2002; Tukker, 2004). While not having to be all managed but coordinated by the company, the extra services would enable potential job opportunities and their benefits (Beuren et al., 2013; Mont, 2002).

Least preferred proposed BME. Paying for extra services was one of the least preferred options. Though contradictory with the preference for counting on them, it is obvious that the BP would be much less affordable with extra costs, particularly if paid upfront in economically depressed areas (K.C. et al., 2011). In addition, using the BP without being the owner was not considered desirable by the Manthali farmer, thus posing potential barriers to other payment schemes (Tukker, 2004).

Opportunities for an improved business model - PSS

Based on the pitfalls and challenges of the current business models analyzed above, an improved, BP-based PSS can be built upon these specific opportunities:

- To offer water pumping systems rather than mere pumping devices; i.e. to give BP-based packages with customized (outsourced) services such as irrigation and water management infrastructure, thereby increasing the usefulness of the BP under a wider range of scenarios.
- To operate with financial aids (e.g. subsidies, microloans), which support the BP affordability, along with co-payment conditions from the end-users. Moreover, extra services offered along with the BP could be attached to these payment methods as well.
- To identify and partner with existing actors to strengthen the supply chains. In Nepal and Malawi, both Collection and Distribution Centers (Rai et al., 2019) and Agricultural Extension Officers (Fisher and Kandiwa, 2014), respectively, act as two-way middlemen that provide technical assistance and agricultural inputs to smallholders. This would reduce service times, create local job opportunities, and increase contact times.
- To partner with NGOs to conduct awareness raising and know-how transfer programs, hence to increase the understanding of the BP as a RE-based technology (K.C. et al., 2011).
- To ensure optimal working conditions whenever required, by the commissioning of additional infrastructure (weirs, diversion canals, gates) that can be outsourced. This will

require, however, further assessment of financing and pay-off methods. Otherwise, BP underperformance could ultimately affect its perceived usefulness amongst farmers.

CONCLUSIONS

Hundreds of BPs are in use in several countries. From these, six cases from Nepal and Malawi were selected and analyzed due to its noticeable differences. In line with the wide range of conditions, the BP owners/users, as well as their neighboring farmers, showed different attitudes on the technical performance of the device and its respective BMEs. Nevertheless, and in line with the CVD approach, instead of aiming to a tailor-made top-down solution for specific situations, the present paper shows how embracing such a diversity could enable co-created richer—yet not perfect—solutions to fulfil several (and at times opposed) needs while coping with different restrictions.

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