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

J. C. Intriago Zambrano, R. van Dijk, J. Michavila, E. Arenas Pinilla, J. C. Diehl and M. W. Ertsen

ABSTRACT

Pumped irrigation is a way to intensify smallholder production. In this context, the Dutch company aQysta has developed the Barsha pump (BP), the first-ever commercial version of the spiral pumps. BPs, however, face several constraints that affect the decision-making and access of smallholders to this and other agricultural technologies, and thus to their benefits. On this subject, Product Service System (PSS) is a type of business model able to potentially cope with a number of restrictions of different nature. 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. Six cases of the use of BPs have been addressed in Nepal and Malawi. Both primary and secondary data, analyzed qualitatively under the analytic induction approach, were collected through unstructured interviews and Q-methodology. Evidence shows a wide range of (non-)technical facilitating and hampering conditions for the BP, as well as preferences of the smallholders in regard 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.

Key words | Barsha pump, business model, hydro-powered pump, irrigation, Product Service System, smallholder

J. C. Intriago Zambrano (corresponding author)
R. van Dijk
M. W. Ertsen
Department of Water Management, Faculty of Civil Engineering and Geosciences,
Delft University of Technology,
Stevinweg 1, 2628 CN Delft,
The Netherlands
E-mail: *j.c.intriagozambrano@tudelft.nl*

J. Michavila
aQysta BV,
Molengraaffsingel 12, 2629 JD Delft,
The Netherlands

E. Arenas Pinilla
ICAI School of Engineering, Comillas Pontifical University,
Calle de Alberto Aguilera 25, 28015 Madrid,
Spain

J. C. Diehl
Department of Design Engineering,
Faculty of Industrial Design Engineering,
Delft University of Technology,
Landbergstraat 15, 2628 CE Delft,
The Netherlands

INTRODUCTION

Given the significant number 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 objectives (Giordano *et al.* 2019). A way to improve (or enable) access to and control of irrigation water is by – yet not limited to – 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, and thus are (too) cost-intensive, or even inaccessible, for many smallholders due to the continuous use of these inputs (Chandel *et al.* 2015); moreover, they affect environmental quality due to their gaseous emissions and noise. Comparatively, more environmentally sound technologies, and at times less expensive ones, are renewable energy (RE)-based water pumps (Gopal *et al.* 2013). From these, hydro-powered pumping (HPP) technologies – i.e. those hydro-mechanically driven by the water

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they lift – give 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 an HPP device traditionally referred to as a 'spiral pump', first reported during the 18th century (Ziegler 1766) and applied after the late 1970s in a number of countries (Morgan 1984; Naegel 1998; UNEP 2015; Intriago Zambrano *et al.* 2019). Roughly 150 BP units have been deployed since 2014 in Nepal, and 13 units since 2018 in Malawi (aQysta, personal communication, July 26, 2019), two of the main markets for the BP. However, the pump in these countries has to deal with market inefficiencies caused by, amongst others, underdeveloped supply chains, economic constraints, and lack of knowledge, which consequently limit the access of smallholders to this as well as other agricultural technologies, and thus to their benefits (Giordano *et al.* 2019).

Nepal and Malawi, moreover, present several characteristics that render them flagship examples of challenges in smallholder farming in South Asia and sub-Saharan Africa, respectively. In Nepal, the agricultural sector represents 27.6% of the GDP, and involves roughly 65% of the labor force. Of the total smallholder farms, though being more than half of Nepal's farmlands, barely 15% are irrigated (Karki *et al.* 2020). Along the same lines, Malawi holds 30% of its GDP by agriculture, which in turn comprises 64% of the working population (Chinseu *et al.* 2019). About 90% of Malawian agricultural revenues come from 1.8 million smallholders, yet the irrigated farmlands are barely 20% of the total farmlands (FAO 2015). Additionally, smallholders of both countries – having a substantial reliance on rainfed production – are much more vulnerable to climate-change-driven effects such as erratic rainfall, floods, and droughts (FAO 2015; Karki *et al.* 2020).

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 the Product Service System (PSS) (Mont 2002). In addition, some authors state that a participatory process of co-creation/co-design (at both integrated and strategic product design levels) (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 the exception of a few authors (Devisscher & Mont 2008; Corti *et al.* 2013), these models have not been studied within the agricultural sector – let alone their co-created versions. Also, none of them have addressed the specific case of water pumping technologies for smallholder farming.

In that perspective, Delft University of Technology and Comillas Pontifical University, as part of larger doctoral research focused on the deployment of HPP technologies in low-income settings (Intriago Zambrano *et al.* 2018), are exploring the co-creation and implementation of affordable and clean pumped irrigation systems for smallholders, based upon novel technologies like the aQysta BP. 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) to 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 – thus during the respective dry seasons to ensure a strong interaction of the farmers with the BPs – based on the following criteria: (1) at least one BP must have been posing a continuous presence for $\geq$2 months; and (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. It is worth mentioning that this is a cross-sectional study, hence single-point data collection from each case was conducted.

Data collection

Primary data, both quantitative and qualitative in nature, was collected during the field visit period, and triangulated mainly by: (1) unstructured interviews with BP users, other smallholders (non-BP users), and experts (authorities, NGOs) relevant to the chosen communities; and (2) Q-methodology.

Q-methodology is an increasingly popular quali-quantitative technique to study human subjectivity in regard to any phenomenon (Dziopa & Ahern 2011). It is deemed to be a highly participatory method – thus relevant for the present study – in which participants acquire an active role in developing their points of view, rather than becoming mere data sources (Donner 2001; Ellingsen *et al.* 2010). Furthermore, this method was additionally chosen because its reliability does not depend on the sample size of respondents but rather on their diversity of opinions (ten Klooster *et al.* 2008), and hence is suitable for working under the CVD approach described above. In this particular study, Q-methodology was administered to the smallholders with statements related to the adoption and use of the BP, as well as preferences for extra products and services to enhance its benefits.

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

Business model canvas

The description of business models in both Nepali and Malawian cases, and the analysis of the building blocks and their interactions will be done by means of the Business Model Canvas tool, as designed by Osterwalder & Pigneur (2010).

RESULTS AND DISCUSSION

Description of current business models

The business models around the BP, both in Nepal and Malawi, are substantially product-oriented; namely, they present a strong component in selling a product – the pump – with few or no additional services linked to it. However, their main differences lie in: (1) the channels through which the BP are delivered to smallholders; (2) the way the BP is purchased; and (3) the final cost of the BP for the end-user. Tables 1 and 2 show the business models' building blocks and their interrelations, in Nepal and Malawi, respectively, in accordance with the Business Model Canvas (Osterwalder & Pigneur 2010).

Figure 1(a) and 1(b) show schematically the BP business models in Nepal and Malawi, respectively. The Nepali model is characterized by allocating the BPs to the farmers either by means of the governments (national, provincial, or local) or retailers, the former being much more common than the latter. Through retailers, the farmers would have to pay the full upfront cost at once, whereas through the governments normally they pay 10% of the total cost due to subsidies allocated to RE-based irrigation technologies. In contrast, the Malawian model allocates the BPs either directly from aQysta's national branch or through international NGOs. The former offers facilities to pay off the BP over time in periodic instalments, whereas the latter considers a single upfront payment after a roughly 50% subsidy. Despite their differences, both business models in Nepal and in Malawi have in common a strong focus on installation and commissioning, with the detriment of a weak after-sales contact, particularly related to (periodic) maintenance and servicing of BPs as well as the timely delivery of spare parts.

There is highly limited reported information on prior experiences of business models in Nepal and Malawi around HPP-based smallholder irrigation. Moreover, very few authors have conducted studies around other RE-technologies, particularly on solar-based pumping systems. Kunen *et al.* (2016) elaborates on four NGO-funded cases in Nepal, where the key components were capacity building, market development activities, and long-term service, in which the pumping system is a means to improve livelihoods and not a goal on itself. Affordability is achieved by a mix of public or private subsidies and microloans paid in instalments. Closas & Rap (2017) address it from a broader and more generic perspective, and elaborate on technological and financial constraints while deploying such systems in low-income settings. More remarkably, Shrestha (1996)

Table 1 | BP business model in Nepal

PARTNERS	ACTIVITIES	PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
– aQysta Netherlands – National/ Provincial governments – Retailers	– Negotiation with governments to allocate public budget – Installation and commissioning of BPs	– Offering to smallholders a low-cost, environmentally sound hydro-powered pumping technology, able to pump 24/7 at virtually zero operation cost	– Sales through retailers – Sales through governments – aQysta Nepal install the pumps – Servicing on-demand provided by aQysta Nepal for the next two years – After-sales limited to servicing	– Smallholders, mainly from the hilly region, lacking secured irrigation water
	KEY RESOURCES – aQysta Nepal headquarters – aQysta Nepal staff – BPs – Transportation		**CHANNELS** – National/Provincial governments (subsidized pumps) – Retailers	
COST STRUCTURE – Shipping spare parts from abroad – Installation and commissioning of BPs		**REVENUE STREAMS** – Governmental budget (government buys pumps and allocates them subsidized later) – Retailers' upfront purchase		

Table 2 | BP business model in Malawi

PARTNERS	ACTIVITIES	PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
– aQysta Netherlands – NGOs – Agricultural extension agencies	– Negotiation with NGOs to allocate budget/ pumps – Approach to agricultural extension agencies, to inform about the pump – Installation and commissioning of BPs	– Offering to smallholders a low-cost, environmentally sound hydro-powered pumping technology, able to pump 24/7 at virtually zero operation cost	– Sales through NGOs – aQysta Malawi install the pumps – Servicing on-demand provided by aQysta Malawi for the next two years – After-sales limited to servicing	– Smallholders lacking secured irrigation water
	KEY RESOURCES – aQysta Malawi headquarters – aQysta Malawi staff – BPs – Transportation		**CHANNELS** – aQysta Malawi – NGOs	
COST STRUCTURE – Shipping spare parts from abroad – Installation and commissioning of BPs		**REVENUE STREAMS** – NGO's budgets for pump allocation – Instalments from smallholders to pay off the pump		

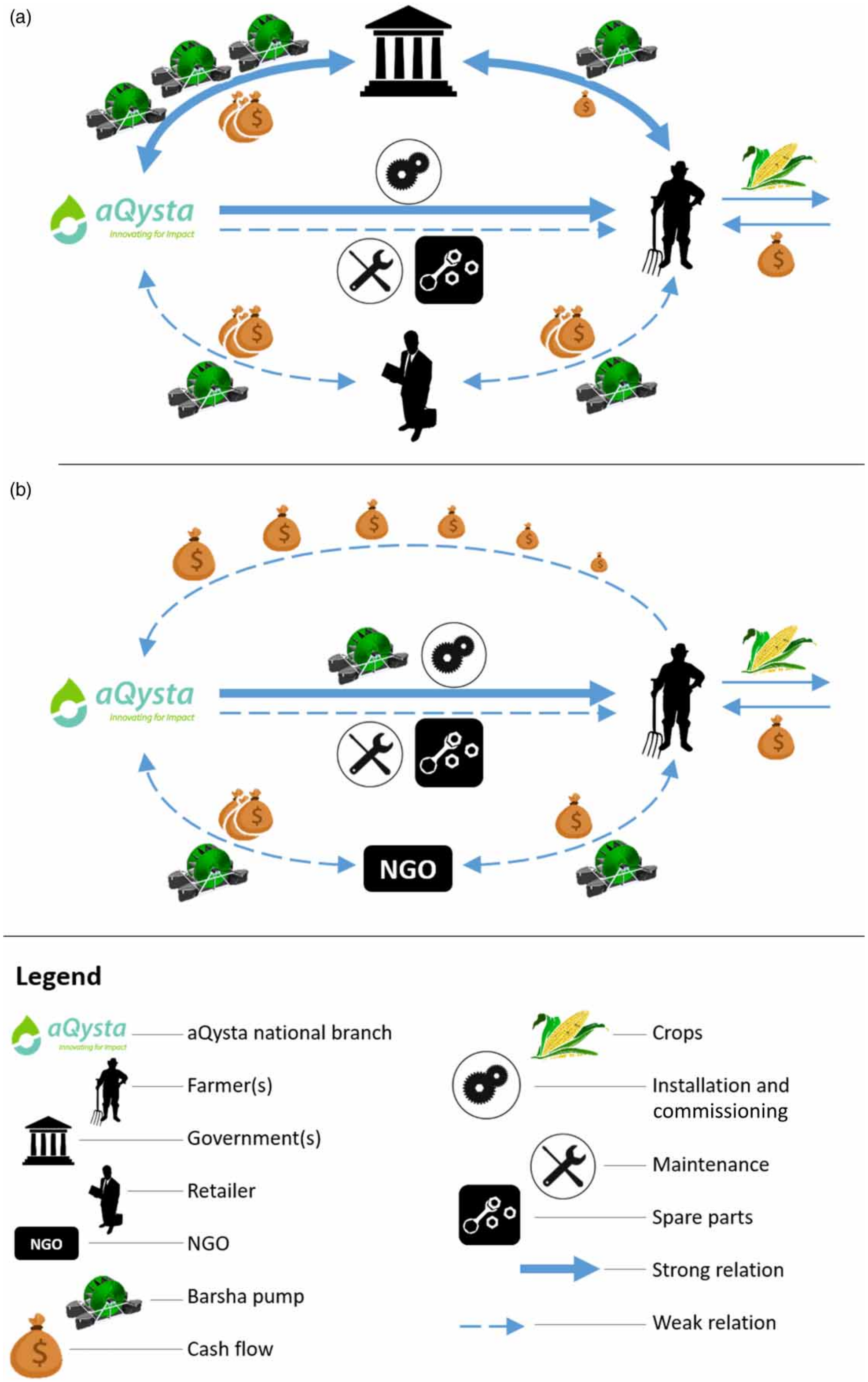

Figure 1 | Schemes of BP business models and their respective legend; (a) and (b) correspond to the business models in Nepal and Malawi, respectively.

identified – already more than two decades ago – key problems and required conditions for optimum implementation of these systems; however, it seems paradoxical that even nowadays those remain somehow the same in the cases analyzed in this study.

Brief description of cases

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 3.

Relying on six cases, three per each country, might seem non-optimal for drawing generalized conclusions with respect to co-creating a business model. However, and particularly strengthened by the nature of Q-methodology (ten Klooster *et al.* 2008; Ellingsen *et al.* 2010), it certainly enables study of the phenomenon of BP use in detail, with richer qualitative information than any quantitative approach would offer (Miles *et al.* 2013).

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 although with two broken waterwheel paddles, and 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 two other community-owned diesel water pumps on the riverside, which are used by the neighboring farmers to irrigate their respective farms. The latter require fuel input, resulting in operation costs of 600 NPR (~ €4.80) per hour per farmer. Nevertheless, in general those neighboring farmers prefer 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 condition, 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 wash 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 a 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 farmers. 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 the 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 a plastic lining to tackle this issue. Although this lining is not provided as part of any BP-marketed package, the company is interested in reaching a high performance for this demonstration site, hence the offer.

Case 5: Tedzani. This farm is an experimental site, intended to test BP feasibility in the Shire River. Its

Table 3 | 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 labor
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 about the BP operation – Skeptical about BP efficiency, though they think the owner made a good decision	– Curiosity about the BP operation	N/A

conditions, however, are challenging: too deep to anchor the BP, the water speed too low next to the banks, a rapidly fluctuant water level, and housing crocodiles. If this installation becomes 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 the 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, and as such they inquired after a BP, which was provided after paying a deposit. Yet, they find the pumped flowrate insufficient compared with other (conventional) water pumps. This occurs due to the mismatch in the irrigation water supply and demand, associated with the lack of efficient irrigation systems (e.g. drippers, sprinklers) and buffer storage infrastructure (e.g. tanks, reservoirs). As a consequence, water surplus continuously pumped through the night is not stored but simply flows off. Moreover, 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; Weng 1994; Naegel 1998), 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), (non)existence of external elements (e.g. reservoirs, centrifugal pumps) affected the perceived usefulness of the BP. Although not part of any of the aforementioned visited cases, according to aQysta there is another Nepali community in which the BP was deemed to be undesirable since it might impede the provision of a subsidized diesel water pump (aQysta, personal communication, June 11, 2019). By contrast, 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 (Weng 1994; Swinnen 2015; Giordano *et al.* 2019). In both Nepal and Malawi, aQysta rely only on a centralized office; as a consequence, all the site-dependent after-sale services (e.g. repairs, maintenance) are reduced 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 are capable of coping with several barriers (e.g. unaffordability, promotion of use, gender inequity) (Fisher & Kandiwa 2014; Bista *et al.* 2018; 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 & Crago 2017) and substantial market distortions (Closas & Rap 2017). Moreover, the technology is prone to be deemed a mere handout due to the lack of empowerment. In some cases, subsidies can be out of the reach of many smallholders due to remoteness or institutional barriers (Gauchan & Shrestha 2017; Paudel & Crago 2017). Unlike Nepali BPs, which are largely subsidized by the local governments, the Malawian ones do not rely on such mechanisms (although they were previously subsidized by UNDP), hence their unaffordability is worsened in the latter case. Therefore, flexible payment methods, e.g. instalments, are 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 (Surendra *et al.* 2011). If proper maintenance is not given to the BP, its lifetime will be severely compromised. Like many other newly introduced (RE) technologies, the BP has been observed to require substantial follow-up support and maintenance assistance, as well as transfer of know-how (Gewali & Bhandari 2005; Johnson & 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 (Surendra *et al.* 2011).

Least preferred existing BME

In Sokhu Besi, where the BP was in operation within its 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 Surendra *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 theft and vandalism prevention measures (e.g. locks, chains, fences) 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 understanding of the farmers of the technology (Surendra *et al.* 2011). The maintenance of the BP, though not specialized, is seen as complex by the Sokhu Besi and Lele farmers. This perception might be exacerbated by the lack of know-how that would enable local partners and/or owners to perform it (Johnson & 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 to be undesired.

Most preferred proposed BME

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

Least preferred proposed BME

Paying for extra services was one of the least preferred options. Although 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 (Surendra *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).

Co-creating along with smallholders

In accordance with Casali *et al.* (2018) the involvement of several stakeholders is a main requisite to cope with the complexities of business models, as it happens usually with technological deployments in low-income settings. Such is the case of the agricultural technology supply chains in Nepal and Malawi, whose weaknesses easily jeopardize the successful adoption and sustained use of a water pumping technology. However, engagement with BP-smallholders, as vulnerable stakeholders whose voices might not be considered legitimate enough to be heard (Derry 2012), is a long process that requires trust, constant capacity-building and empowerment (Mena *et al.* 2010; Candelo *et al.* 2018). Nevertheless, this study must be understood as a first attempt to enable those commonly unheard smallholders – by means of a participatory methodology – to contribute with their share of (indigenous) knowledge in a smoother transfer of (water pumping) technology.

Opportunities for an improved business model – PSS

Based on the pitfalls and challenges of the current business models analyzed above, which in accordance with past studies (Shrestha 1996; Kunen *et al.* 2016; Closas & Rap 2017) remain in the same order of restrictions, 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. Whenever required, additional civil infrastructure that ensures optimal operation of BPs (weirs, dams, funnels) should be considered as an integral part of these systems. Nevertheless, the technical–financial feasibility of these components, due to their potential complexity, is worth a separate study.
- To operate with financial aids (e.g. subsidies, microloans), which support 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 & 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 an RE-based technology (Surendra *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 their 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 for 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. Notwithstanding the participatory capabilities of the employed methods, this study has become just a first attempt at hearing unheard smallholders, aiming towards the co-creation of knowledge on improved BP-based business models.

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