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EDITED BY
Ali Shahnazari,
Sari Agricultural Sciences and Natural Resources University, Iran

REVIEWED BY
Mohammad Valipour,
Payame Noor University, Iran
Ali Akbarzadeh,
Researcher in Irrigation and Drainage, Iran

*CORRESPONDENCE
Juan Carlo Intriago Zambrano
J.C.IntriagoZambrano@tudelft.nl

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Discourses on the adoption of the Barsha pump: A Q methodology study in Nepal and Indonesia

Juan Carlo Intriago Zambrano[1]*, Jan-Carel Diehl[2] and Maurits W. Ertsen[1]

[1]Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands, [2]Department of Sustainable Design Engineering, Faculty of Industrial Design Engineering, Delft University of Technology, Delft, Netherlands

Improved water management is an important strategy to support smallholder farming, and thus to foster food security and improved livelihoods. Within this strategy, technologies like water pumps, especially those operating on renewable energies, are key, as they are more environmentally sound and affordable alternatives. Their successful and sustained uptake is a complex process—largely dependent on the adopter and its surrounding context—usually overlooked by traditional linear technology-transfer approaches. By means of Q methodology, we explored cross-cultural discourses around the adoption of the Barsha pump (BP), a self-reliant hydro-mechanical device that does not require any external input than flowing water to operate. We administered the method to 43 (non-)farmer respondents linked to Nepali and Indonesian smallholder farming systems. We identified three relevant discourses, one of them bipolar in nature. These three groups accounted for 39, 36, and 28% of the total explained variance of our study. The first one identified BP's potential early adopters. The second discourse embodied the (stereotypical) highly dependent smallholder. The last one characterized (contrasting) views around the BP as an enabler of potential service-oriented business models to achieve wellbeing. These results reflect the need for a shift of mindset toward new ways of understanding technological change in smallholder settings. On the one side, simplistic one-size-fits-all models cannot connect to the diversity of issues and opinions as we found. On the other side, it is virtually impossible to produce tailored solutions to satisfy each of those individual realities. We propose possible adoption pathways that may lead to the exploration of innovative and adaptable business models that serve the diversity of smallholder farming needs more effectively.

KEYWORDS

water management, smallholder farming, Barsha pump, hydro-powered pump, Q methodology, Nepal, Indonesia

Introduction

Eradication of hunger and malnourishment is a main goal on the global agenda [Sustainable Development Goal (SDG) 2: Zero Hunger] (United Nations, 2020a; Villarreal, 2022). Achievement of this target would require the global food production to increase roughly by 50% within the next 30 years (FAO, 2017). Such a substantial growth will largely stand on the shoulders of smallholder farmers (SF) (Giordano et al., 2019), who are mostly clustered in South and Southeast Asia, and to a lesser extent in sub-Saharan Africa (Samberg et al., 2016). Appropriate interventions in this sector would not just contribute to global food security, but also (in)directly to poverty alleviation by boosting local economies (SDG 1), reduction of gender inequalities by empowering female smallholder farmers (SDG 5), and protection and promotion of farming systems biodiversity (SDG 15) (Poole, 2017; Giordano et al., 2019).

Given that limited water access is one of the main challenges that SF face, investing in water management technologies is a cornerstone strategy in the accomplishment of these SDGs (Giordano et al., 2019). In this respect, small private irrigation through diesel- and electric-pump sets is an already dominating strategy across Asia, and a steadily increasing one in sub-Saharan Africa (de Fraiture and Giordano, 2014). Spread of these conventional technologies can lead to negative environmental impacts associated with water over-abstraction and polluting emissions. Additionally, unaffordable and even inaccessible fuels and grid-electricity might render these water pumps cost-prohibitive—or ultimately inapplicable—for the poorest and most remote SF (de Fraiture and Giordano, 2014). Water pumps operating on renewable energy (e.g. solar, wind, and hydro) appear as more environmentally sound, more financially affordable, and as such more appropriate alternatives for remote, off-the-grid locations (Gopal et al., 2013). Within this category, hydro-powered pumps (HPPs) have a number of additional advantages compared to other water pumps. Hydro-powered pumps use a concentrated, widely available and predictable energy source, are more cost-effective, are mechanically less complex and more robust, and as a result are typically more efficient (Fraenkel and Thake, 2006). Still, HPPs have been largely neglected, seemingly due to the development of other forms of readily available energy (e.g. electricity, fossil fuels). Nevertheless, hydro-powered devices have regained an interesting momentum in recent times (Intriago Zambrano et al., 2019).

Abbreviations: BP, Barsha pump; SDG, Sustainable Development Goal; SF, Smallholder farmer; HPP, Hydro-powered pump. Q, Q methodology; NF, non-farmer; NGO, Non-profit organization; YKRMW, Yayasan Komunitas Radio Max Waingapu; CFA, Centroid Factor Analysis; PCA, Principal Component Analysis; EV, Eigenvalue; F1, Factor 1; F2, Factor 2; F3+, Factor 3 (positive pole); F3-, Factor 3 (negative pole).

Many authors have studied adoption patterns and constraints of conventional water pumps in SF settings (Burney and Naylor, 2012; Getacher et al., 2013; de Fraiture and Giordano, 2014; Gebregziabher et al., 2014; Namara et al., 2014; Ali et al., 2016; Mottaleb et al., 2016; Chuchird et al., 2017; Abebe and Shewa, 2018; Mottaleb, 2018; Theis et al., 2018). Only a few have explored the adoption of renewable energy-pumps, typically scoped on solar-driven systems (Burney and Naylor, 2012; Nederstigt and Bom, 2014; Ali et al., 2016; Zhou and Abdullah, 2017; Shah et al., 2018; Theis et al., 2018; Gupta, 2019; Wong, 2019; Bastakoti et al., 2020). Similar to any other agricultural innovation, adoption of (non)conventional water pumping technologies is a complex process that largely depends on the receiver and the surrounding context (Alexander et al., 2020; Llewellyn and Brown, 2020; Olum et al., 2020). The highly heterogeneous (social and biophysical) nature of smallholder agriculture, which complicates this relationship between farmer and context further (Ruben and Pender, 2004), must be first understood in order to implement effective strategies adapted to local realities (Vanlauwe et al., 2014). Traditional technology-push approaches have generally overlooked a broader range of smallholders' decision-making variables and contextual conditions, thus resulting in discouragingly low and slow adoption rates (Röling, 2009; Giordano et al., 2019; Alexander et al., 2020; Olum et al., 2020). In general, adoption literature has widely disregarded farmers' perceptions as a crucial influencing variable in the technology uptake process (Foguesatto et al., 2020), which is the research gap we tackle in this study.

The Dutch startup company aQysta has developed a novel waterwheel-powered HPP—commercially known as the Barsha pump (BP)—which it markets as a sustainable water pumping solution for SF (aQysta, 2022). This company, headquartered in a high-income setting, has gradually introduced the pump to the Nepali and Indonesian (Sumba Island) markets through a technology-push approach (technology and contexts are explained in Section 3). This market approach has resulted in a device that is not necessarily familiar for SFs nor exactly aligned with their respective values. Potential disagreements of viewpoints may thus emerge between the manufacturer/provider and the end-users during this technology provision process.

This study, as part of a larger doctoral research at Delft University of Technology on sustainable smallholder irrigation (Intriago et al., 2018), investigates cross-cultural discourses and perceptions on the adoption of the BP—and their possible (dis)agreements—, thereby addressing the research gap mentioned above. In this respect, the key novelty of this work is the systematic analysis of SFs' perceptions from different contexts on the adoption/delivery of a novel renewable energy technology for irrigation (i.e. BP), and its implications for relevant stakeholders (e.g. manufacturers, technology providers, practitioners, researchers).

For the purpose of our study, we leveraged on the etic[1] cross-cultural research approach (Buil et al., 2012; Stone et al., 2017). Through this approach, we sought to compare systematically the discourses of stakeholders linked to different regions/contexts. The etic approach requires using the same instrument to measure the phenomenon (i.e. adoption of the BP) from outside their context, thereby facilitating a comparative analysis between Nepali and Sumbanese SFs. Moreover, through the participatory nature of Q methodology (explained in detail in section 2), we analyzed the diversity of emerging viewpoints and discussed their areas of (possible) consensus and disagreements (results and discussion, sections 4 and 5). Lastly, based on those discourses, we drew possible adoption strategies that may be relevant for both manufacturers and policymakers (section 6). Our findings would be relevant for aQysta and enrich the policy and academic debates on HPP technologies and their uptake by (smallholder) farmers.

Materials and methods

Q methodology (henceforth Q) is a technique developed by William Stephenson in the 1930s to study human subjectivity (Stephenson, 1935). Q is employed to explore the different viewpoints people may have with regard to a (complex) phenomenon. It is considered a simple yet innovative adaptation of Spearman's factor analysis method. Q has a mixed qualitative-quantitative nature, hence it is sometimes referred to as a semi-quantitative method (Stenner and Rogers, 2004; Watts and Stenner, 2005a). Though initially envisaged for the field of psychology, Q has been effectively applied across a number of other disciplines such as management, nursing, human geography, tourism, and rural research (Watts and Stenner, 2012). Due to its bottom-up, culture-sensitive participatory nature, Q has been successfully applied within cross-cultural studies (Ahmed et al., 2012; Stone et al., 2017). Therefore, we deemed it suitable for our study to explore both contrasting and convergent culture-influenced perspectives on the adoption of the novel BP.

Q is executed by asking participants (P-set) to distribute a set of stimuli (Q-set)—typically, yet not limited to, written statements—across an 'agree/disagree' (or similar) ranking scale, usually within a forced quasi-normal distribution grid (i.e. sort). The completed sort is done in accordance with each participant's perspective, therefore capturing the subjectivity regarding the topic under study. Ultimately, the processing of collected sorts allows the identification of discourses or perspectives across the P-set, commonly referred to in Q as factors (Watts and Stenner, 2012). Therefore, every time we use the term 'factors' throughout this work, we refer to the unique discourses/viewpoints that emerge from the collected data.

1 The 'etic' and 'emic' are the two predominant research approaches in cross-cultural research. Whereas the etic approach studies the phenomenon from outside its context, thus focusing on universal constructs and theories, the emic one does it within the specific context.

Research method

Q is better understood through the four typical methodological stages, namely (1) Research design, (2) Data collection, (3) Analysis, and (4) Interpretation. The first stage relates to the definition of the research question, concourse, Q-set, P-set, and sorting grid. The second one refers to the administration of the instruments (i.e. statements, sorting grid, surveys) to the participants and subsequent collection of sorts. The third one corresponds to the analysis of collected sorts and production of factors, usually through dedicated software. The last stage implies the construction of meaningful narratives for each of the identified factors, typically by complementing rich qualitative complementary data.

Research design

Concourse development

We constructed the concourse based on primary and secondary data sources. The primary sources were a focus group discussion with experts from different disciplines, as well as semi-structured interviews with key local informants in each of the target study areas, both conducted in March 2019. The secondary sources consisted of documents from a literature review about the development of hydro-powered pumping technologies over time, conducted between June 2018 and June 2019 (Intriago Zambrano et al., 2019).

We processed and synthesized the concourse by the methods of categorization, thereby deleting or combining similar statements. For this process, we considered two sets of categories for statements: (1) variables that influence the adoption of water pumping technologies for smallholder irrigation (affordability; technical performance; environmental soundness; ease and convenience of installation, operation and maintenance; extension and access to information; observability and trialability; legal and institutional framework), and (2) building blocks that may shape business models around the BP (additional products and services (technical assistance, infrastructure, agricultural inputs); ownership; entrepreneurship and job-enabling conditions; involvement of external parties).

Q-set construction

As a result, we selected 38 written statements (in the English language) about elements that might influence SF adoption of the BP. This number ensured sufficient coverage of different themes of concern, yet provided a manageable amount of items. The Q-set fits within methodologically acceptable

TABLE 1 Features of the sorting grid.

Sorting criteria	Strongly disagree							Strongly agree
Sorting point	−4	−3	−2	−1	0	+1	+2	+3	+4
Nr. Statements	2	3	4	6	8	6	4	3	2

ranges (Watts and Stenner, 2012). The 38 statements were translated into the Nepali and Indonesian languages [Appendix A in Supplementary material (Intriago Zambrano, 2020)] by a parallel translation technique (Buil et al., 2012). To ensure cross-cultural calibration equivalence, we customized the data collection instruments considering elements unique to each context (Buil et al., 2012). This considered currency (Nepali rupee or Indonesian rupiah), land size (Ropani or Hectare), and local types of land tenure.

Sorting grid design

We selected a slightly leptokurtic, 9-sorting point, forced inverted quasi-normal distribution as sorting grid. It was designed with a −4 to +4, "strongly disagree" to "strongly agree" scale (Table 1). Given the exploratory nature of this research, the leptokurtic shape allowed more (nearly) neutral positions to provide more space for indifference, neutrality or doubtfulness amongst participants (Watts and Stenner, 2012).

P-set sampling techniques

We sampled two groups of participants: (1) SF and (2) other relevant non-farmer (NF) stakeholders linked to smallholder farming systems [i.e. technology developers, non-profit organizations (NGOs), experts, governmental authorities. We asked NFs to sort as if they were farmers themselves. By collecting insights on how NFs perceive SFs, through the lens of their own discipline, we aimed to explore possible (mis)alignments of viewpoints.

We identified SF participants from selected communities by purposive sampling. Participants were selected based on two criteria: (a) bearing certain degree of familiarity with the BP (i.e. owning, using, having used, or having seen), and (b) posing sociodemographic diversity (e.g. gender, income, distance to main urban centers, farm conditions, etc.). We identified them with the assistance of aQysta (Nepal) and the local NGO Yayasan Komunitas Radio Max Waingapu (YKRMW) (Indonesia).

We sampled NF participants by purposive and snowball sampling, based on their degree of familiarity with the BP and Nepali/Sumbanese smallholder farming systems. We identified them by personal references, iterative internet searches, and authorship of related (non)academic literature.

Administration (data collection)

We resorted to face-to-face sorting for SF participants. It was conducted on-farm, at the respondent's household, or village (outdoors) meeting point. Lack of proper furniture and exposure to elements was occasionally challenging. The places were usually close to each other within selected farming communities. SF sorting sessions took place either collectively or individually, depending on the circumstances of each site and the number of available participants. Staff of aQysta Nepal and YKRMW, as native Nepali and Indonesian speakers, facilitated the sorting sessions. Facilitators offered four-stage assistance to participants: (1) pre-sort instructions (i.e. introduction to researchers, study aim, sorting mechanism); (2) preliminary rough sorting with the three-pile technique; (3) step-by-step sorting guidance; and, (4) on-demand clarification of instructions and statements. Each SF participant was provided with a sorting sheet (with written instructions) and the 38 printed statements alongside supporting illustrations. We offered the statements in shuffled and randomly numbered laminated paper cards (40 x 50 mm). We allowed SF participants to reallocate the cards over the distribution until they were satisfied.

We also collected two sets of complementary data to be able to further analyze sorting choices: (1) sociodemographic and farm data, through a structured survey, and (2) the reasoning about the ranking of statements and trade-offs, through an unstructured post-sort interview. The interview frequently resulted in short answers due to post-sort fatigue from the respondents. We relied on sort sheets, survey sheets and written notes to record the collected data. We took pictures of those documents, which were ultimately synchronized with an encrypted cloud storage service. Complementarily, we recorded on-site physical and social observations for triangulation purposes.

We administered Q to NF participants by the online platform Easy HtmlQ[2] (Banasick, 2020). This technique allowed reaching out to an international NF audience, and could cope with the limitations of the COVID-19 global pandemic crisis (Omary et al., 2020). The platform contained the required sorting instructions and step-by-step guidance. Unlike its face-to-face counterpart, the online version relied purely on the original English-written statements. We collected complementary sociodemographic information and sorting reasoning through the platform itself.

Analysis

We analyzed the dataset of collected sorts with KADE v1.2.0 (Banasick, 2019), which was preferred over other analytical software because of its nonproprietary GNU General Public

2 The versions of this platform used for this study are available for some time at: https://barshapump-nepal.netlify.app and https://barshapump-indonesia.netlify.app.

License, simple and easy-to-use graphical user interface, and cross-platform availability. Due to the exploratory nature of the study, we conducted several iterative analyses, considering three different P-set segmentations, namely SF, NF, and a SF+NF combination (SF-NF). Considering that country is usually a poor cultural proxy (Buil et al., 2012; Taras et al., 2016), we neglected per-country segmentations of the dataset, thereby allowing the factors to emerge by themselves according to the analytical methods that we describe below.

Factor extraction method

Centroid Factor Analysis (CFA) and Principal Component Analysis (PCA) usually provide roughly similar results. Their main difference lies in PCA providing the mathematically best solution, thus the one that should be numerically accepted. In contrast, because our aim is to explore the data through a judgmental, investigatory approach, we preferred CFA as the technique to extract factors in our study. PCA was still used iteratively to conduct the scree test as one of the factor retention criteria (Watts and Stenner, 2012).

Factor retention criteria

To define the number of retained factors, we explored several decision-making statistical criteria: (a) Kaiser-Guttman criterion [Eigenvalue (EV) threshold], (b) Significantly loaded sorts, (c) Humphrey's rule, (d) PCA-based scree test (Watts and Stenner, 2012), (e) Horst Centroid Factors (Hu et al., 2018), and f) Distinct statements threshold (Cammelli et al., 2019). We underpinned these criteria by looking at the highest number of significantly loaded sorts ($p < 0.05$) in each factor and the most distinctive sorts grouping in the respective Q maps (Yoshizawa et al., 2016). It is worth remarking that there are no "best" criteria to retain factors (Watts and Stenner, 2012): each factor selection needs to be explained specifically, as we will do below in Sections 4 and 5.

Factor rotation method

We resorted to Varimax as factor rotation method. This technique was preferred over by-hand rotation, because it maximizes the total variance explained—hence the identification of salient factors—in line with the inductive, bottom-up exploratory essence of this study (Watts and Stenner, 2012). We required the majority of common variance to load significant sorts ($p<0.05$) automatically. As a result, confounded sorts were excluded from the analysis.

Interpretation and validation

We interpreted retained factors, namely respondents' viewpoints, using the holistic method of crib sheets system, as described in Watts and Stenner (2012). We split and interpreted bipolar factors whenever the respective Q maps showed a clearly opposite placing of their significantly loaded sorts (Watts and Stenner, 2012). We validated the interpretation by asking iterative feedback to the highest NF loaders of each factor via e-mail (Robbins, 2005). Though desirable, we could not validate with the highest SF loaders due to the COVID-19 pandemic mobility restrictions.

The settings of technology choice

The Barsha pump

The BP, named after "rain" in Nepali language (वर्षा), is a waterwheel-driven manometric HPP that relies on twin planar spiral pipes to build pressure (Intriago Zambrano et al., 2019). This pump constitutes the commercial version of a device invented back in the mid-16th century (Ziegler, 1766), usually referred to as spiral or Wirtz pump (Intriago Zambrano et al., 2019). Currently, aQysta's main markets are Nepal, Malawi and Indonesia (aQysta, 2018a).

The latest version of the BP is offered in three variants, suitable for both riverine and canal settings of different depths and widths. The BP needs a mooring or anchoring mechanism to avoid the pump to be swept away. At times, it might also need some basic site preparation, such as water funneling through improvised, on-site made structures (Figure 1a). To operate, it requires a minimum input flow rate of 300 L s^{-1} and water speed of 1 m s^{-1}. Depending on specific contextual conditions, the BP is capable to pump a maximum[3] of 20–80 m^3 d^{-1} (0.23–0.93 L s^{-1}) up to 20 m of head and 1 km far, and is suitable to irrigate up to 2 ha of land. Its size is roughly 1.5 m in diameter and it weighs about 90 kg (Figure 1b) (aQysta, 2018b).

As any other HPP of its kind, the BP works solely on the kinetic energy of the water (Intriago Zambrano et al., 2019), hence virtually posing costless operation. Its foreseen maintenance is limited to basic cleanup of the waterwheel from entangled objects, (re)adequacy of the installation site to ensure proper operation, and replacement of any damaged part.

Study areas

South and Southeast Asia are two of the most (densely) populated regions in the world (Roser et al., 2013). Despite being the largest staple producers (Ritchie and Roser, 2020) and having the largest SF share (Samberg et al., 2016), these regions also are highly food-insecure (FAO, 2019) and undernourished (Roser and Ritchie, 2013). Within this challenging setting, the BP is slowly penetrating the agricultural markets of two of the poorest and least developed SF areas in these regions: the mid-hills in Nepal (United Nations, 2020b) and the island of Sumba in Indonesia (Vel and Makambombu, 2010).

3 Maximum pumping specifications are traded-off, i.e. it is not possible to meet them all simultaneously.

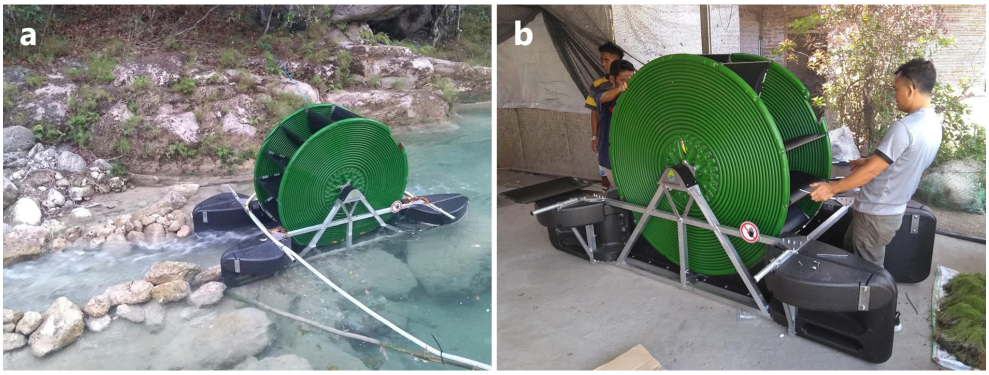

FIGURE 1
The Barsha Pump. **(a)** Commissioned and operating in the Mbatakapidu River, Eastern Sumba. **(b)** Assembly before its installation.

Mid-hill Nepal

Agriculture in the mid-hills region of Nepal deals with conditions that are notably complex. Albeit this region holds the vast majority of Nepali SF, Roka (2017), GC and Hall (2020), it receives much less agricultural investment than the more fertile Terai flatlands (Devkota et al., 2020; GC and Hall, 2020). The challenging topography of the mid-hills region with its associated remoteness exacerbates its SF poverty. Many farmers cultivate less than 0.50 ha, and many are actually (nearly) landless (GC and Hall, 2020). Furthermore, due to social, legal and political constraints, women SF are particularly more disadvantaged despite their substantial agricultural participation (Roka, 2017).

aQysta offers the BP in Nepal through a typically product-oriented delivery model: the farmer pays to become the owner of a BP. Nepali SFs are able to reach the technology through direct contact with aQysta Nepal or via third parties (e.g. retailers, governments, NGOs). SF usually opt for the latter, given that financial aids—installments, subsidies, micro-credits—are frequently part of the technology provision schemes.

Sumba Island

One of Indonesia's most remote islands, Sumba does have potentially profitable paddy-suitable valleys across its geography; however, these are only available to wealthier and more influential inhabitants, thereby relegating the poorest SF to dry, humble-yield hillside farmlands (Vel, 2008; Vel and Makambombu, 2009). This issue is more exacerbated in Eastern Sumba, with its predominant subsistence farming (Vel, 2008). SF, particularly from the so-called *tani*-class[4] have the weakest access to resources throughout the island (Vel and Makambombu, 2009, 2010). From these, women, youth and ethnic minorities are the most disadvantaged (Vel and Makambombu, 2009, 2010; Nugrohowardhani, 2014).

aQysta's national Indonesian office is in Jakarta; the main BP provider in Sumba is YKRMW. The BP is offered through a service-oriented delivery model. Instead of selling the device to the farmers, the organization provides a BP-based irrigation service. YKRMW not only owns, installs, operates and maintains the BP, but also provides additional irrigation infrastructure (e.g. piping, sprinklers) to ensure that irrigation water arrives on time at the farms. Additionally, the organization offers training and technical assistance to improve farming practices. In exchange, SF pay for the service with part of the sales revenues, under the so-called pay-per-harvest business model of the EASI-Pay project (NWO, 2020).

Selected farming communities

We selected three farming communities in mid-hill Nepal (Ratamata, Manthali and Lele) and four in Sumba Island (Kalu, Mbatakapidu, Mondu Lambi and Lai Pandak). We chose them (1) because these communities are using/have used at least one BP (hence SF are exposed to the technology), and (2) accessibility for the study (e.g. distance, traveling time, remoteness) from the urban centers in mid-hill Nepal (Lalitpur) and eastern Sumba (Waingapu). Details of the selected locations are presented in Figure 2 and Table 2.

Results

Data collection

We invited 30 SF participants, 18 from Nepal and 12 from Indonesia, which resulted in 7 and 12 valid collected sorts respectively (Table 3). Each sorting took roughly 40 minutes to complete. Sortings with illiterate participants, who required

4 Emic term that refers to the lowest societal layer, which includes both farmers and unemployed/incomeless people (Vel and Makambombu, 2010).

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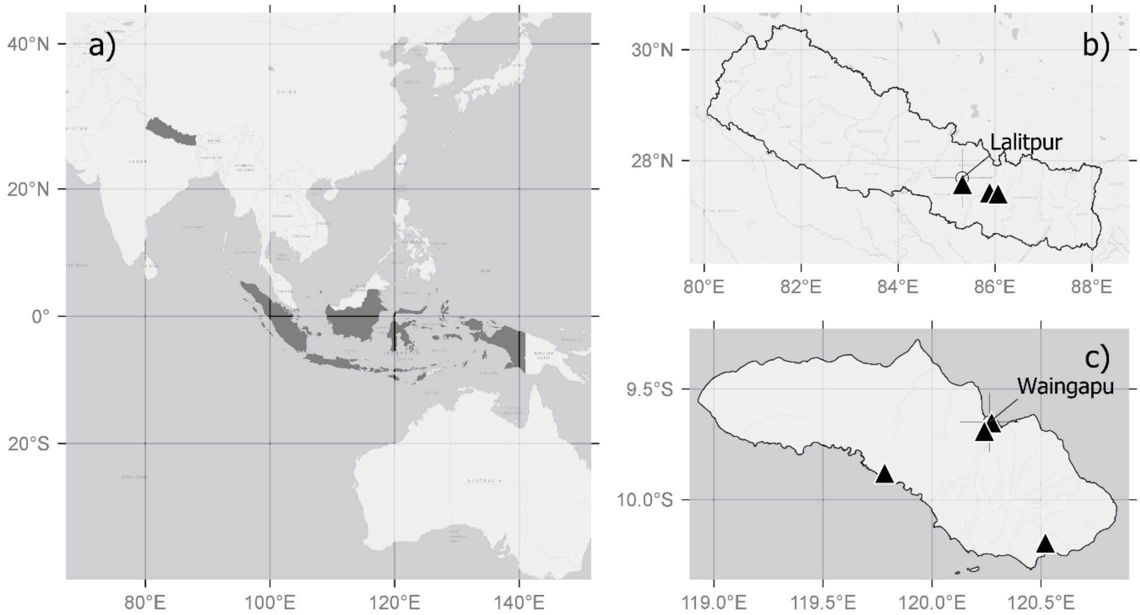

FIGURE 2
Geographical locations of study sites. **(a)** Countries of study (dark shade): Nepal and Indonesia. Black triangles and crosshairs mark studied farming communities and main urban centers in **(b)** Nepal and **(c)** Indonesia (Sumba island), respectively.

TABLE 2 Characteristics of selected farming communities.

	Nepal			Indonesia			
District	**Sindhuli**	**Ramechhap**	**Lalitpur**	**East Sumba**			
Community	**Ratamata**	**Manthali**	**Lele**	**Kalu**	**Mbatakapidu**	**Mondu Lambi**	**Lai Pandak**
Distance[1] (km)	88	129	16	2	9	86	128
Traveling time[2] (h)	3.5	5	1	0.1	0.5	2.3	2.2

[1] Rough distance measured from each operative urban center in mid-Hill Nepal (Kathmandu) and Eastern Sumba (Waingapu).
[2] Rough traveling time by car.

sustained assistance, took longer times. Reasons for dropout were: participants declining to participate ($n = 3$), producing unsuccessful sorts (e.g. sorting out of the grid, unfinished sorting) ($n = 7$), and producing invalid sorts (e.g. nonthought sorting due to inebriation) ($n = 1$).

Although gender balance was a P-set sampling criterion, it was not always possible to fulfill this in the field due to composition of and interaction within each farming community.

We invited 73 NF participants through e-mails, websites (contact forms), and social networks. 24 respondents produced valid sorts (Table 4). The response rate was influence by respondents not answering at all ($n = 42$), declining due to disagreement with the topic or the methodology ($n = 2$), or not answering after first contact ($n = 5$). It is worth noticing that none of the invited governmental representatives decided to take part in the study.

The total valid sorts [Appendix B in Supplementary material (Intriago Zambrano, 2020)] produced P-set sizes of 19 (SF), 24 (NF) and 43 (SF+NF), which in turn resulted in P-set/Q-set ratios of 0.50, 0.63 and 1.13. Both sizes and ratios are within ranges accepted by Q methodologists (Watts and Stenner, 2012). The female/male ratios of valid sorts were 0.46 (SF), 0.50 (NF) and 0.48 (SF + NF). Female farmers generally face a more limited access to resources (Poole, 2017; Giordano et al., 2019); thus, we acknowledge these slightly male-skewed ratios might pose biases and/or incompleteness of the topic under study.

TABLE 3 Characteristics of sampled SF P-set.

	Nepal			Indonesia			
District	Sindhuli	Ramechhap	Lalitpur	East Sumba			
Community	Ratamata	Manthali	Lele	Kalu	Mbatakapidu	Mondu Lambi	Lai Pandak
Administration	CW	IN	IN	3-person round			
Place	CMP	HH	Farm	HH	CMP	HH	Farm
Facilitator	aQysta Nepal			YKRMW			
Valid sorts[1] (F)	0 (2)	0 (0)	1 (1)	0 (0)	3 (3)	1 (1)	1 (1)
Valid sorts[1] (M)	5 (13)	1 (1)	0 (1)	3 (3)	0 (0)	2 (2)	2 (2)

[1]Total (both valid and non-valid) number of participants in brackets.
CW, collective workshop; IN, individually; CMP, community meeting point; HH, household; F, Female; M, male.

TABLE 4 Characteristics of sampled NF P-set.

	Nepal				Indonesia				Total
Role	TD	NGO	EXP	GR	TD	NGO	EXP	GR	
Invited participants	9	18	31	4	1	3	7	0	73
Valid sorts (F)	3	3	0	0	1	1	0	0	8
Valid sorts (M)	6	4	3	0	0	1	2	0	16

TD, technology developers; NGO, non-profit organizations representatives; EXP, expert; GR, government representatives; F, female; M, male.

Analysis

Using the factor retention criteria as shown in Table 5, we decided to retain three factors for both SF, NF, and SF-NF segments [Appendices C, D and E in Supplementary material, respectively (Intriago Zambrano, 2020)]. This choice aligns well with the retention criteria related to number of loaded sorts and Q maps (see Table 5). However, it is worth stressing that we did not rely on those criteria because of any form of superiority over others; rather, we took them as a compass that matched our experience from the respective field observations (Watts and Stenner, 2012). Our iteratively exploration of correlations between factor- and Z-scores of those segments (also accounting two- and three-factor solutions), produced only secondary insights that we decided to leave out in the analysis [Appendix F in Supplementary material (Intriago Zambrano, 2020)]. We could identify the third factor of each segment as bipolar (Figure 3), as it expressed two opposed, mirror-image perspectives across loaded sorts (Watts and Stenner, 2005b). Our three factors accounted for 39% (SF), 36% (NF) and 28% (SF-NF) of the total explained variance. The SF-NF variance might be perceived as relatively low, especially in light of the frequently accepted range of 35–40% (Watts and Stenner, 2012). A low variance is not necessarily problematic, however (Cuppen, 2010; Watts and Stenner, 2012). Although an SF-NF four-factor solution would actually have offered a higher total explained variance, we selected the three-factor one for its clearer and more consistent factor clustering (Figure 3C). Characteristics of the three factors (i.e. 1, 2, 3+, 3-) are indicated in Table 6; their raw scores can be found in Table 7.

Factors interpretation

In this section, we provide the interpretations of the three SF-NF factors, based on the analysis of factor scores (Table 7) and crib sheets [Appendix G in Supplementary material (Intriago Zambrano, 2020)], as described in Watts and Stenner (2012). Each factor's interpretation contains a first paragraph with a summary of relevant statistical and demographic information (i.e. participants who compose the group); this gives the reader a quick overview of how and who has been included in that factor. The second paragraph (and third in case of our bipolar factor 3) offers the narrative of the factor, building on the information contained in each of the crib sheets. That narrative should be understood as how an 'ideal' respondent of certain factor would think based on those scores. Additionally, to underpin the interpretative narrative regarding the Q-set stimuli, we share the number of a statement and its factor score; i.e. (28: +4) would mean that statement number 28 was scored +4 (in accordance to Table 7).

We focused on interpreting the combined SF-NF P-set segment as it includes the total universe of respondents (both SFs and NFs), hence offering a higher diversity of potential viewpoints. Furthermore, the combination allows exploring how SF and NF hold to one another, regardless their categories of

TABLE 5 Factor retention criteria, description and results.

Criterion	Description	Factors		
		SF	NF	SF-NF
Kaiser-Guttman	Retain factors with EV ≥1	4	3	8
Significant sorts	Retain factors with ≥2 SL sorts at statistical significance $p < 0.01$ SL = 2.58 √(Q-set)	2	5	6
Humphrey's rule	Retain factors if cross-product of the two highest loadings >2SE or >SE (less strict rule) SE = 1/√(Q-set)	1 (>2SE) 5 (>SE)	2 (>2SE) 5 (>SE)	1 (>2SE) 8 (>SE)
Scree test	Based on the EVs scree plot, retain factors before the straightened section of the curve	2	4	2
Hors Centroid Factors	Algorithm self-limits factors (on 30 iterations at 1 10^{-4} cutoff threshold)	3	3	4
Distinct statements threshold	Retain factors with ≥5 distinct statements at statistical significance $p < 0.01$ to ensure interpretability	4	3	4
Number of loaded sorts	Maximum amount of SL sorts between analyzed N-factor solutions	3	3	3
Q maps	Highest graphical variance between factors	3	3	3

EV, eigenvalues; SL, significantly loaded; SE, standard error.

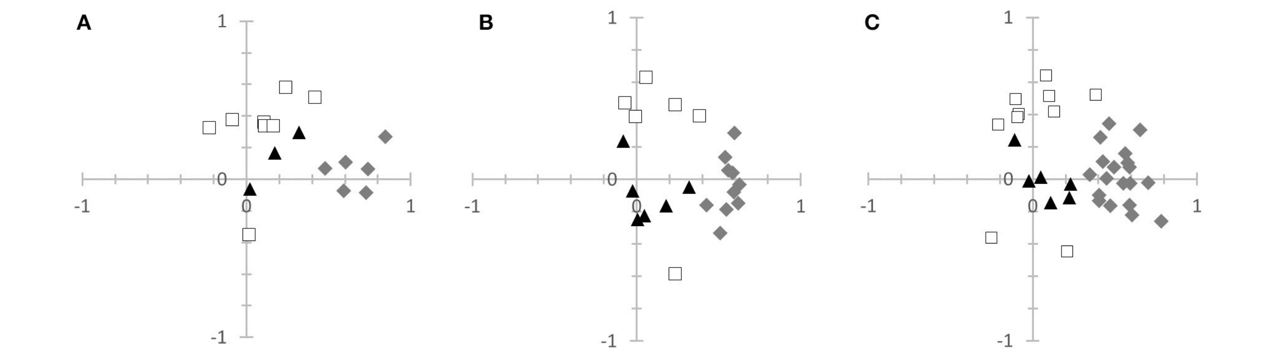

FIGURE 3
Q maps of **(A)** SF, **(B)** NF, **(C)** SF-NF. Gray diamonds, black triangles and white squares represent significantly loaded sorts of factors 1, 2, and (bipolar) 3, respectively.

countries, roles and genders (Figures 4, 5), thereby facilitating a cross-context comparison. Figure 4 shows a Sankey diagram with the cumulative distribution of respondents across factors, regarding their country (Nepal/Indonesia), roles (SF/NF) and gender (female/male). One would perhaps initially assume that actors from the same country (left extreme of the figure) may think in a similar manner, meaning that they will (mostly) group in the same factor. However, as Figure 4 shows, actual factors' composition (right extreme of the figure) is rather heterogeneous. F1, for instance, includes (non)farmer female and male actors from both Nepal and Indonesia. Similarly, as another example, though in a much smaller group, F3+ includes participants from almost all categories.

Whereas labeling of factors is common practice among Q researchers, we refrained from assigning descriptive names to the three factors. We believe that Q enables us to embrace richness and diversity of voices, thus oversimplifying that diversity in labels may actually be counterproductive to that potential of Q.

Factor 1

Factor 1 (F1) has an EV of 6.20 and explains 14% of the total variance; 19 participants are significantly loaded in this factor (nine SFs and 10 NFs) (Figure 5C). The SFs in factor 1, predominantly males of Sumbanese origin (Figures 4, 5B) form a heterogeneous group in terms of experience, age and education. Most of them belong to small households (≤ 4 people) and perceive themselves as economically poor, with farming being their only source of income. These SFs do not own BPs (the majority rent them) and work part-time with a commercial orientation in rented plots. The NFs of F1, most of them

TABLE 6 Factors characteristics.

Statement	SF				NF				SF-NF			
	1	2	3+	3-	1	2	3+	3-	1	2	3+	3-
No. of SL sorts	6	3	7	1	10	6	5	1	19	6	8	2
Composite reliability	0.960	0.923	0.966	0.800	0.976	0.960	0.952	0.80	0.987	0.960	0.970	0.889
SE of factor Z-scores	0.200	0.277	0.184	0.447	0.155	0.200	0.219	0.447	0.114	0.200	0.173	0.333
% explained variance	22	10	7		14	13	9		14	9	5	

1, 2, 3+ and 3- relates to the (bipolar) factors of each segment.
SL, significantly loaded; SE, standard error.

highly acquainted with the BP, are mainly ($n = 6$) technology developers, and further include three NGOs managers and one expert.

F1 symbolizes a consistent BP early adopter who think such adoption improves quality of life (28: +4) by saving farming labor (29: +4) and offering better overall performance than conventional water pumps (27: +1). The main strengths of the BP appear in its virtually costless operation (3: +2) and its relatively sufficient provided flow rate (24: +2) and pressure (25: +2). Although the BP might require on-site adaptations (7: 0), its (simplicity of) design would allow becoming empowered and independent actors (22: +3; 15: −3; 16: −3) who do not demand (intensive) assistance to install (10: −3; 19: +1; 20: 0), operate (12: −4; 21: +2) and maintain the BP (17: −4; 23: +1). In fact, its user-friendly features might encourage becoming BP-entrepreneurs (e.g. service providers in communities) (34: +3). Despite all these perceived advantages, however, F1 members may refrain from strongly advocating and recommending the BP (30: +1). Perhaps due to poor economic status and/or strong sense of independence, they feel skeptical about acquiring additional goods (e.g. seeds) (33: 0). They do not see local governments as enablers to access the BP (33: 0).

Factor 2

Factor 2 (F2) has an EV of 3.84 and explains 9% of the total variance. Six participants loaded significantly in this factor: one Sumbanese SF and five NFs (Figures 5A,C). The only loaded SF is a young adult, highly educated woman with low farming experience (< 1 year), who belongs to a small household (≤4 people). She farms with rented land and BP, and work part-time with a commercial orientation; she perceives herself as being economically poor. NFs encompass two highly BP-experienced technology developers, one NGO representative and two experts.

Ideal loaders of F2 reflect highly dependent SFs, who need external (financial) assistance to not only install (1: +4; 20: −2), operate (2: +3) and maintain the BP (17: +3), but also to grow more efficiently with it (16: +4). They see the BP as a device that does not easily integrate with natural (8: −4; 7: −1) and built environments (9: −4). This results in lower perceived BP benefits; for instance, its advantageous costless operation would not outpace its relatively high upfront cost (3: −2). They also consider the BP as less useful for profitable farming than conventional pumps (26: −3; 14: −1; 27: −1), which may also explain their interest in additional irrigation infrastructure to enhance BP benefits (4: +2). It is obvious that they would not advocate the BP (30: 0), nor would consider that it improves their quality of life (28: 0). They do not see BP-related jobs and entrepreneurship (13: 0; 11: −2) in the local communities as an attractive option, despite the BP's relative straightforwardness in commissioning and maintaining (23: +1; 19: +1). On the contrary, they would rather see another person first farming with the BP before adopting it (32: +3), preferably provided by a local actor (31: +1).

Factor 3

Factor 3 has an EV of 2.30 and explains 5% of the total variance. Ten participants loaded significantly in this bipolar factor, eight in a positive pole (F3+) and two in a negative one (F3-) (Figures 3C, 4). Both roles see the BP as extremely interesting, but in highly different modes: F3+ members prefer to use the pump as a service, whereas F3- members aim to own the pump to use it.

F3+ includes one highly educated, inexperienced (<1 year) young-adult Sumbanese SF, and three lowly educated, well experienced (>10 years) mid-age SFs (two Nepali and one Sumbanese) (Figures 4, 5C). The young Sumbanese SF farms with commercial orientation on rented land, and considers himself as economically poor. The mid-age SFs practice subsistence farming on their own plots, and consider themselves as economically average. None of them is owner of any BP. F3+ also comprises three NGO representatives and one expert (Figures 4, 5C), all well acquainted with BP operation in SF contexts.

F3- consists of a mid-educated, mid-age male Nepali SF (Figures 4, 5) with extensive farming experience (>10 years), who belongs to a large household (≥ 10 people). He farms full-time with a strong commercial orientation in many contiguous,

TABLE 7 Raw factor scores of SF, NF and SF-NF.

Nr.	Statement	SF				NF				SF-NF			
		1	2	3+	3−	1	2	3+	3-	1	2	3+	3-
1	I need financial aid from an external organization or person to deal with the installation and commissioning costs required by the Barsha pump	1*	−3	4*	−3	2*	4	4	−1*	1	4*	3	2
2	I need financial aid from an external organization or person to deal with the operation costs required by the Barsha pump	1	−1	1	1	−1	3*	0	−1	0*	3*	1*	−3*
3	The savings on the operation of the Barsha pump-because it does not need electricity or diesel-is worth the (relatively) high upfront cost	3	0	3	2	3	−1	1	4	2	−2*	2	2
4	I prefer to pay more to have extra optional infrastructure in my farm (e.g. sprinklers, drippers), so I can make better use of the water provided by the Barsha pump	0	−2	0	−3	1	0	1	0	−1	2	1	−2
5	I prefer to pay more to have additional technical assistance (e.g. irrigation advices, growing advices) beyond just irrigation water provided by the Barsha pump	−2	−3	0*	4*	0	−3*	1	0	−1	1*	−2	3*
6	It is more convenient for me to make use of the Barsha pump without being the owner	−1	0	2*	−4*	−1*	1	−4*	4	−2	−3	4*	−4*
7	The natural landscape does not require considerable modifications to install the Barsha pump	−1	0	−2	−1	−1	−4	−1	−3	0	−1	−1	−1
8	The water bodies do not require considerable modifications to install the Barsha pump	−1	0	−3	−1	−1*	−3	1*	−4	−1	−4*	−1	1*
9	The existing irrigation infrastructure (e.g. canals, gates) does not require considerable modifications and adaptations to install the Barsha pump	−1	0	−2*	0	−2	−4	0	−4	0*	−4	−4	3*
10	An external organization or person must be in charge of installing and commissioning the Barsha pump	−2	3	−1	4	−3*	2	3	2	−3*	1	1	4*
11	Some members of the community could have job positions by being involved in the installation and commissioning of the Barsha pump	−2	2	−3	2	1	1	−2*	3	−1	−2	0	0
12	An external organization or person must be in charge of operating the Barsha pump	−4	−4	−1*	2*	−4	1	−3	0	−4*	−1	0	−1
13	Some members of the community could have job positions by being involved in the operation of the Barsha pump	0	−2	−1	0	0	0	−3*	3*	−2	0	−1	−3
14	I prefer to use the Barsha pump over electricity- or diesel-based water pumps because it operates on clean energy	4*	−1*	1	1	2	4	−3*	2	3	−1	4	0
15	An external organization or person must assist me in how to irrigate with the water provided by the Barsha pump	−3*	0	4*	0	−2	3*	−2	−2	−3	1*	3*	−2
16	An external organization or person must assist me in how to grow more efficiently with the water provided by the Barsha pump	−2	−2	3*	−1	−2	2	2	0	−3*	4	3	0*

(Continued)

TABLE 7 (Continued)

Nr.	Statement	SF				NF				SF-NF			
		1	2	3+	3−	1	2	3+	3-	1	2	3+	3-
17	An external organization or person must be in charge of maintaining the Barsha pump	−3	−4	−1	0	−4*	2*	−1	−1	−4*	3	1	−2*
18	Some members of the community could have job positions by being involved in the maintenance of the Barsha pump	−1	1	−2	−1	1	1	−4*	3	−1	−3	0*	−4
19	I think my farm facilitates the installation and commissioning of the Barsha pump	2	0	1	0	0	0	0	0	1	1	0	−1
20	I think the Barsha pump can be installed straightforward in my farm without much expertise	−3*	4*	1	0	0	−2	−1	−2	0	−2	−1	0
21	I think my farm facilitates operating the Barsha pump	0	1	2	0	1	−1	0	0	2	0	−1	0
22	I think the Barsha pump can be operated straightforward in my farm without much expertise	3	2	1	0	1	0	−2	1	3*	0	0	−1
23	I think that a person without much expertise can provide maintenance to the Barsha pump	2	3	0	−1	0	−1	1	−1	1	1	−3*	0
24	I think the Barsha pump can provide enough volume of water to my farm for producing year-round	0	1	0	−1	3*	−3	0	−2	2	−2	−3	1
25	I think the Barsha pump can provide enough water pressure to my farm for producing year-round	2	1	0	−2	1	−2	−1	0	2*	−1	−2	−1
26	The Barsha pump helps me more than other water pumps in increasing my agricultural production	1	−1	2	1	−2	−2	0	−1	0	−3*	0	1
27	The Barsha pump helps me more than other water pumps in growing new cash crops	2	2	−1	1	−1	1	−1	−1	1	−1	1	0
28	The Barsha pump improves my quality of life	4*	−1	2	1	2	0	0	1	4*	0	2	2
29	The use of the Barsha pump in my farm saves me labor	3	−1	3	−2	4	0	−2	2	4*	−1	1*	−3
30	I would recommend other farmers to use the Barsha pump as well	1	2	0	1	2	0	2	1	1	0	0	1
31	I would prefer a person from my own country to provide me with the Barsha pump	−1	1*	−4	−2	0	−1	1	1	−1	1	−2	1
32	I prefer to see another person using the Barsha pump before using it myself	−4	0*	−3	−2	3	1	2	−3*	0	3*	−1	−1
33	I think the Barsha pump would be more valuable if seeds are provided along with it	1	1	0	−3*	−1	2	2	1	0	0	2*	0
34	I would like to have entrepreneurial training on the Barsha pump, so I can start my own business	1	3	1	−4*	4	3	3	1	3	2	2	−2*
35	The laws of my country facilitates me to have access to the Barsha pump	0	−2	−1	3	0	−2	4*	−2	0*	2*	−4*	3*
36	The national government facilitates me to have access to the Barsha pump	0	−1	−4	3	−3	−1	−1	−3	−2	0	−3*	1
37	The local government facilitates me to have access to the Barsha pump	0	−3	−2	3	−3*	−1	3	0	−2	2*	−2	4*
38	NGOs operating in the area of my community facilitate me to have access to the Barsha pump	0	4	0	2	0	0	0	2	1	0	0	2

*Distinguishing statement at $p < 0.01$.
1, 2, 3+ and 3- relates to the (bipolar) factors for each P-set segment.

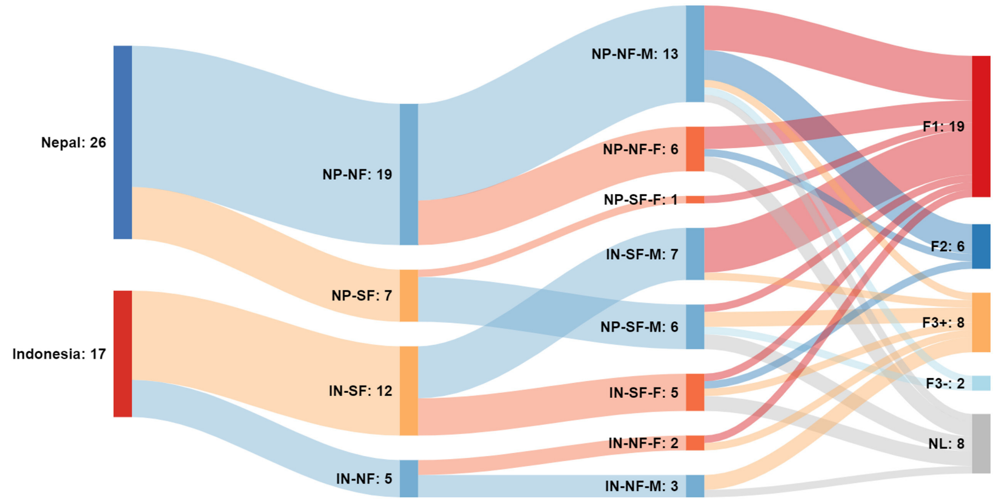

FIGURE 4
Cumulative distribution of respondents of SF-NF segment across factors (F1, F2, F3+, F3-) with respect to their countries, roles and gender. Acronyms: Nepal (NP), Indonesia (IN), female (F), male (M), non-loaded respondents (NL).

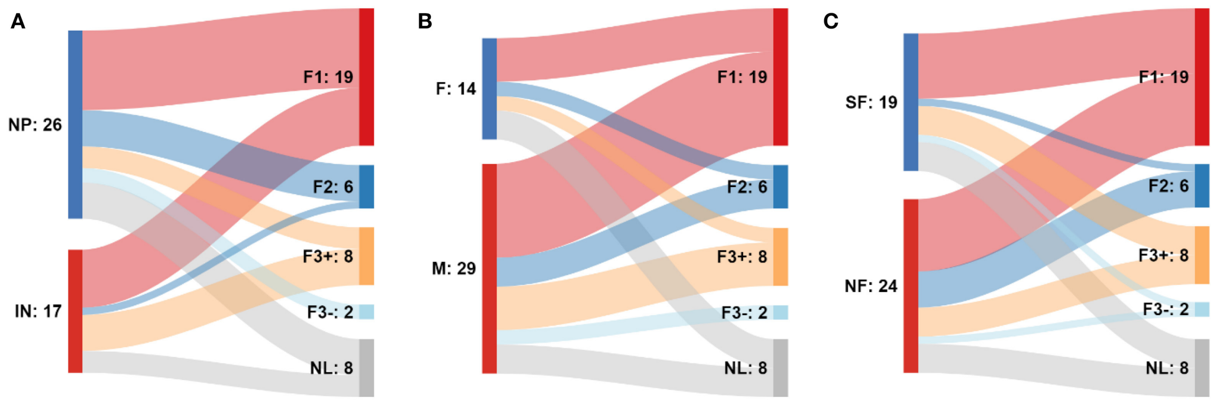

FIGURE 5
Noncumulative distribution of respondents of SF-NF segment across factors (F1, F2, F3+, F3-) regarding **(A)** country, **(B)** gender, **(C)** role. Acronyms: Nepal (NP), Indonesia (IN), female (F), male (M), non-loaded respondents (NL).

rented plots, which he irrigates with his own two BPs and with groundwater. He considers himself as economically average. F3- also includes one male NF who is a highly BP-experienced technology developer (Figures 4, 5).

Ideal respondents of F3+ emerge as potential users of a BP-based irrigation service rather than owners of a product (6: +4), underpinned by the preference of external actors providing goods (e.g. seeds) (33: +2) and services (e.g. irrigation technical assistance, BP operation) (15: +3; 12:0) beyond the mere sale of the BP—although they might also be reluctant to incur in associated additional expenses (5:−2). Given a perceived simplicity of installation (9: −4; 7: −1) and maintenance (23: −3), F3+ members also believe to a certain extent that other community members can benefit from BP-related employments (18:0; 11:0). There is a general distrust in local actors (e.g. governments, NGOs) (36: −3; 37: −2; 38: 0) and laws (35: −4) as facilitators of the BP; in fact, foreign stakeholders should ensure BP access (31: −2) according to F3+ members. They have opposing views about the technical performance of the BP. On the one hand, they acknowledge the advantages of the BP regarding its clean (14: +4) and costless operation (3: +2), which can turn into better profits (25: +1) compared to conventional water pumps. On the other hand, they also perceive lower water pressure (25: −2) and flow rate (24: −3) as main downsides of the BP. These views may explain that they would not require seeing other people farming first with the BP (32: −1) and that they would be cautious in recommending others its use (30: 0).

Opposed to the positive pole, idealized loaders of F3- arise as financially independent actors (2: −3) with a strong sense of ownership toward the BP (6: −4). This could be related to the BP's limited outputs, generally just enough for a single household, hence the reluctance to pool/share the BP. Their skepticism about the BP's easiness of installation (9: +3; 8: +1; 20: 0; 19: −1; 7: −1) and operation (22: −1) may lead them to prefer an external stakeholder to commission it (10: +4). They are unwilling to pay for additional goods besides the BP (4: −2), though they consider desirable to afford some services such as farming technical assistance (5: +3). These farmers appear to be interested to secure what they have instead of investing, and thus risking, in new means of production. This may explain why they do not consider local BP-related job positions (18: −4; 13: −3; 11:0) and/or entrepreneurship (34: −2) as suitable choices. They see local (non)governmental actors (37: +4; 38: +2; 36: +1) and laws (35: +3) as enablers to access the BP; logically, they are therefore inclined to receive it through a local person (31: +1). Likely, these local actors have a budget allocated for yearly agricultural programs, which farmers may see as an opportunity to benefit from. They recognize the virtually costless operation (3: +2) of the BP compared to conventional water pumps (26: +1), although they do not see any farming-labor savings by using it (29: −3). Nevertheless, they could adopt the BP without seeing it elsewhere first (32: −1), and might recommend others to use it as well (30: +1).

Discussion

Our etic cross-cultural research approach allows comparing viewpoints of different actors linked to Nepali and Sumbanese farming settings. The comparison reveals that perceived adoption of the BP is highly heterogeneous. In fact, results did not show any significantly recognizable consensus statements between the three factors. Ideas on adoption, moreover, do not consistently relate to social constructs like 'country', 'gender role' and 'farming role', but are rather mixed (Figures 4, 5). This is noticeable, for instance, in the disaggregation of male Nepali SF (F1, F3+ and F3-) and female Indonesian SF (F1, F2, F3+), groups which may be otherwise thought of as 'homogeneous' types of farmer. The discourses did not correlate either to education level, land tenure or age of the SF. None of those variables seems to explain the way participants grouped, which holds well with observations that SFs agricultural innovation is a complex process not explainable in terms of simple adoption-diffusion models (Glover et al., 2019). Indeed, SFs' discourses may actually involve even more—and more diverse—drivers than industrial farming (Paudel et al., 2019a,b, 2020; Alexander et al., 2020; Llewellyn and Brown, 2020). The results also show SFs are not a homogeneous group, but rather a category encompassing a wide range of farm and household characteristics (Fan et al., 2013; Fan and Rue, 2020). Without suggesting that cultural identities of individuals are meaningless, we would rather suggest that our results show that BP provision models cannot be simply identified as one delivery model for Nepal and another one for Sumba, for example. On the contrary, country/context, gender and roles heterogeneities may trigger the which innovative and flexible BP provision models can better satisfy the (farming) needs of those diverse backgrounds.

Factor 1

F1 brings a strong discourse similarity between (mainly) male Sumbanese SFs and Nepali NFs (both male and female). These seemingly dissimilar groups show a complementary interest in the BP as an innovative, affordable and easy to operate game changer in low-resource farming settings. Within the Nepali context, however, the NF ideas on options for using a BP is not precisely consonant with the expectation of Nepali farmers. The counterintuitive convergence between NFs from Nepal and SFs from Sumba may be explained by misalignments between technology (alongside its delivery models) and the actual aspirations of SFs in Nepal (Glover et al., 2019).

F1 groups SFs who perceive themselves as economically poor and that do not have any other sources of income than farming. Most of them are Sumbanese SFs who, unlike their Nepali counterparts—who may have more access to technologies and agents of all kinds (Paudel et al., 2019a)—do not have much presence nor choices of agricultural equipment. As such, the evident male SF majority in F1 can reflect the low empowerment position that Indonesian women still face in agricultural decision-making (Akter et al., 2017; Indrayanti and Mochtar, 2021).The pay-per-harvest business model present in Sumba directly reduces the financial and technical burden for a SF to use the BP, making the technology more accessible and affordable, and even an enabler of rural entrepreneurship (Van Loon et al., 2020). Direct and constant intervention of YKRMW as service provider would have supported BP use and likely triggered SFs in F1 to act as early adopters (Llewellyn and Brown, 2020). Nevertheless, we must keep in mind that a pilot project-driven adoption is far from being a steady and sustained BP uptake over time, which would demand a broader synergy between many other actors and processes (Woltering et al., 2019; Devkota et al., 2020; Van Loon et al., 2020).

NF loaders in F1 might see the BP as an agent of appropriate mechanization to boost agricultural production in small and fragmented farms (Sims and Kienzle, 2017; Devkota et al., 2020; Van Loon et al., 2020). Despite NF and SF loaders sharing a similar viewpoint in this factor, during our fieldwork we could not observe a particularly close contact between farmers and BP manufacturer; in Sumba, actually, we could not detect any contact whatsoever. In the Sumbanese case, the service provider seemed to take over that gap successfully—thereby developing SF into actual users of the technology—whereas in Nepal that gap turned their respective F1 loaders into mere aspiring BP users.

Factor 2

F2 is the least heterogeneous cluster, mainly loaded with Nepali, male NFs. The overarching NF ideas appear to build on the (inaccurate, as our results show) stereotypically impoverished, aid-reliant, subsistence-oriented SF (Fan and Rue, 2020; de Brauw and Bulte, 2021). Indeed, F2 members stress the limited access to resources of all kinds that has traditionally characterized SFs (Poole, 2017), and thus the inability to afford and eventually adopt the BP. As such, SFs become actors that (should) largely rely on the external aid of multiple stakeholders. Unlike F1, where limited technological choices increase the desirability of BP, F2 emerges from settings where both BP and SFs are subjected to other interactions between human and technological agents.

We observed those interactions in Nepali farming communities, in which the BP was usually ignored in favor of other pumping choices. In line with what Llewellyn and Brown (2020) suggest, these settings trigger two unfavorable conditions for F2 to adopt the BP: 1) higher upfront costs and comparatively lower performances of the BP in a market already flooded by more affordable and accessible Chinese and Indian technologies (Paudel et al., 2019a; Devkota et al., 2020), and 2) a strongly technocratic, product-oriented approach, alongside weak supply chains of spare parts and expertise (Devkota et al., 2020). Merely selling an artifact, without a proper training nor timely servicing, may severely compromise SF empowerment and education concerning the BP (Van Loon et al., 2020). In view of increasingly feminized farming settings, like Nepal, where gender-insensitive technology reinforces patriarchal roles of mechanized farming (Devkota et al., 2020; Paudel et al., 2020; Sudgen et al., 2020), the BP may even be more compromised.

The allocation of public subsidies to sustainable agricultural machinery (Poudyal et al., 2019), including the BP, may (partially) cope with higher investment required for a BP. However, given the complexity of technology adoption, this is not enough to guarantee sustained uptake, especially when certain institutional arrangements have resulted at times in misuse and ultimate ineffectiveness of subsidies (Gurung et al., 2013; Khatiwada, 2020).

Factor 3

F3, in both its positive and negative poles, is an interestingly rich group with roughly evenly distributed proportions of stakeholders in terms of gender, role and country. This diversity may be related to the opposite positions that an innovation like the BP may bring to existing farming practices and values (Curry et al., 2021).

Where F1 and F2 seem to be related to access/use (or not) of the BP through a linear technology-transfer model, F3 opens up diverging perspectives on innovative BP delivery models (Röling, 2009), including its barriers (Annarelli et al., 2016). Whereas F3+ loaders embrace the BP as an enabler of potential service-oriented business models to achieve wellbeing, F3- poses the rejection of a service-model with its focus on BP ownership. As such, F3 builds on a possible shift of paradigm from the traditional understanding of (agricultural) technology as a 'black-box'—a troubleshooter package deployable at any site—toward the conception of a technology-centered reorganizer of farming practices, as Glover et al. (2017) discuss.

A key concern with respect to innovative business models, such as the service-based F3+ preference, is the resistance to cultural shifts of both technology producers and users (Annarelli et al., 2016), which can be exacerbated in light of possible risk-averse behavior of SFs (Senapati, 2020). These business models would also require financial and organizational arrangements beyond the mere seller-buyer relation (e.g. including policy makers, nonprofit organizations, governmental authorities, etc.) (Röling, 2009; Agrawal and Jain, 2019; Van Loon et al., 2020). Members of F3-, in contrast, show a strong sense of ownership and full exercise of property rights (i.e. use, benefit, modification, transferring) (Cherry and Pidgeon, 2018) over BP and related irrigation water. BP ownership almost became a cultural manifestation, especially for wealthier and more empowered actors, as we could gather from our field observations. This (still dominant) mode of consumption (Demyttenaere et al., 2016) does bring implicit risks and responsibilities — usually referred to as the 'burdens of ownership' (Cherry and Pidgeon, 2018). For the BP, users may end up purchasing a device unsuitable for farm and/or (distance to) water source, as well as the responsibility of BP maintenance and repair.

Implications: Beyond adoption discourses

Each individual respondent in our Q sort represents by her/himself a unique perception on how the adoption of the BP should (not) look like. SF participants responded based on their diverse experiences and expectations. NF participants expressed their vision on what an SF is, and how she/he would (not) react toward the introduction of the BP in her/his community. It is virtually impossible for technology adoption and business models to cater for all those numberless individual realities, wickedly dependent on the interaction of both technology, adopter, and context (Montes de Oca Munguia and Llewellyn, 2020; Olum et al., 2020). With Q allowing us to identify consistent clusters of shared viewpoints, we would argue that potentially attractive one-size-fits-all models

TABLE 8 Suggested pathways to provide the BP with respect to each factor, based on the conceptual framework of Glover et al. (2019).

	Propositions	Encounters	Dispositions	Responses
F1	Burden-less water pump with cost-less operation that converts water in (any form of) well-being	Direct, risk-free contact with the BP, by seeing/trying it and/or witnessing its results	Aspirational hopes toward a device that enables a better quality of life	BP would act as a trigger for SF to access new farming horizons in quality and/or quantity
F2	Affordable, accessible and easy-to-use device, appropriate for remote farming niches with high land fragmentation, where (potential) farmers are not served by other technologies	Direct and sustained contact with the BP, perhaps first through a well-known local early adopter	Openness toward a well-tested device whose benefits have become tangible	Appropriate mechanization in fragmented land contexts, which would demand more robust supply chains to become sustainable
F3+	Burden-free provision of affordable, timely and consistent irrigation water, along with other possible goods and services	Both formal (deliberately organized) and informal (spontaneous) spread of message of an innovative water management system rather than a mere water pumping device	Interest on new farming directions, in which an innovative system aims to provide user satisfaction	Implementation of new BP-based business models would demand bidirectional and more complex interactions of more stakeholders
F3-	Sale of an innovative water pump with emphasis on its comparative advantages	Formal and planned transmission of the advantages of the BP compared to other existing water pumps	Interest on a product that offers comparative advantages in managing irrigation water	Strong post-sale support with accurate troubleshooting that ensures owner satisfaction

cannot satisfy each of these clusters either. There is a need to respond to this diversity, probably with a set of flexible, innovative and adaptable business models that could help in delivering a range of BP-based products and services. The range would not only satisfy (irrigation) needs, but also fulfill personal desires and culture-bound expectations. If properly designed, such wider models for the BP can become inspiration for processes of sustainable agricultural mechanization (Paudel et al., 2019a; Devkota et al., 2020), gender empowerment in increasingly feminized farming settings (Slavchevska et al., 2019; Rola-Rubzen et al., 2020; Sudgen et al., 2020), and potential reduction of inequalities through inclusive positive rural transformation (Chamberlain and Anseeuw, 2019; German et al., 2020; Kyriakarakos et al., 2020; Van Loon et al., 2020).

Designing business models that cover SF needs is beyond the scope of this paper. Nonetheless, given the discourses around the BP adoption that we discussed, we can propose possible pathways/strategies worth exploring. Using the conceptual framework of Glover et al. (2019) about technological change in SF settings, we suggest for each factor propositions and encounters from BP providers, as well as expected dispositions and responses from the prospective SF users (Table 8). These suggestions should be seen as a first outline of new ways to understand adoption of agricultural innovations, as triggers for possible novel business models required for sustainable changes in smallholder agricultural systems (Woltering et al., 2019; Kyriakarakos et al., 2020).

In order to develop different perspectives that still allow to be meaningfully clustered, we would argue that Q is a highly useful method. Q being a powerful technique to study human subjectivity does obviously not mean that its application in rural—and at times remote—smallholder communities is without its issues. Q has to deal as well with a number of general biases that Chambers (2017) coined as the 'rural poverty unseen'. We acknowledge limitations of our own study with respect to spatial (farthest locations were not visited due to time constraints), personal (gender balance was difficult to achieve in some places) and seasonal (our fieldwork took place in dry seasons) biases (Chambers, 2017). Future studies, scoping toward those unexplored conditions, will surely contribute to expand our findings and discussions, thus possibly finding new, undetected discourses around SFs' technological innovation.

Researchers, let alone rural dwellers, are not highly familiarized with Q (ten Klooster et al., 2008). Q can bring curiosity and interest (Schneider et al., 2015; Nordhagen et al., 2017), but also confusion, doubts or even discomfort and stress (Hugé et al., 2016; Weldegiorgis and Ali, 2016; Truong et al., 2017, 2019). In that respect, we observed differences in the responses of Nepali and Sumbanese farmers toward Q. The former seemed more hesitant in translating their thoughts on the sort, whereas the latter showed higher engagement and usually took the initiative to sort by themselves. Either case, the required sorting times frequently ended in tiredness of the respondents. This fatigue may pose an additional source of biases due to the respondent's desire to finish the Q exercise. In these cases, collected answers could be unauthentic (e.g. random, non-thought sorting), or too short and (perhaps) eventually meaningless (e.g. during the post-sort interview), as reported in Truong et al. (2017).

Lastly, low levels of education (and occasional illiteracy) of some smallholders may directly impact the smooth administration of Q, which usually relies on written statements. Assistance and translation becomes crucial in such cases, but could lead to biased responses due to permanent intervention, long sorting times, and possibly disengagement of participants (Truong et al., 2017, 2019; Vargas et al., 2019). Although we did our best to keep these undesired effects to a minimum, we do acknowledge potentially biased responses due to the mentioned reasons. We therefore advocate a gender-balanced empowerment of local researchers regarding Q, so they become—as the ones closer to the local realities and needs of SFs—main actors in the co-production of knowledge and interventions for development.

Conclusion

By means of Q, we have explored discourses on the adoption of the BP in the different smallholder settings of mid-hill Nepal and Sumba Island, Indonesia. Inviting NFs as respondents allowed us to include the understanding of other parties regarding smallholder adoption of technology. Three unique factors—one of them bipolar—emerged from our reductionist analysis and interpretations. None of these perspectives responded directly to the country/community of respondents, nor even to variables usually addressed in literature on agricultural technology adoption (e.g. gender, age, education, land tenure). The factors we identified were highly heterogeneous in nature, concerning both discourses and composition. Some factors revealed alignments of viewpoint between apparently unrelated groups, whereas individuals from certain single groups could also split across factors.

That heterogeneity shows the complexity of smallholders' technological change. This is likely related to the wicked interaction between the (would-be) adopter, her/his context and the characteristics of the technology itself. In light of that complexity, strategies for technological adoption should not be conceived through a one-size-fits-all approach intended for a single "smallholder"category. On the other side, it would be impossible to provide countless tailor-made solutions to cater for every set of individual needs, let alone considering the diversity in smallholder farming. Systematic identification of adoption viewpoints, possibly by employing Q, offers a balanced and sensitive approach to operate on middle grounds in this respect. Q allows discovering diversities in smallholder communities while at the same time providing manageable blocks to draw possible (BP) adoption strategies.

Amongst those strategies, innovative and inclusive business models could be powerful tools to deliver technologies more effectively. These models would be able to create value for manufacturers, while better satisfying the (farming) needs of diverse SFs. Manufacturers and providers should consider that these models also require dynamic synergies between human and technological agents, beyond the traditional and shortsighted producer-user linear relationship. If properly designed, they can stimulate positive and inclusive technological agricultural transformation.

Data availability statement

The datasets generated/analyzed for this study can be found in the DataverseNL (https://doi.org/10.34894/AURC5E) (Intriago Zambrano, 2020).

Ethics statement

The studies involving human participants were reviewed and approved by human research Ethics Committee of Delft University of Technology. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JI: conceptualization, methodology, investigation, formal analysis, writing—original draft, and visualization. J-CD: writing—reviewing and editing, supervision, and funding acquisition. ME: methodology, writing—reviewing and editing, supervision, funding acquisition, and project administration. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The supplementary material of this study can be found in the DataverseNL (https://doi.org/10.34894/AURC5E) (Intriago Zambrano, 2020).

References

Abebe, A., and Shewa, A. (2018). Contribution of adoption of motorized water pump on the household farm income of smallholder farmers: evidence from Lake Abaya and Chamo Basins of Gamo Gofa Zone, Southern Ethiopia. *J. Dev. Agric. Econ.* 10, 22–27. doi: 10.5897/JDAE2017.0868

Agrawal, S., and Jain, A. (2019). Sustainable deployment of solar irrigation pumps: key determinants and strategies. *Wiley Interdiscip. Rev. Energy Environ.* 8, e325. doi: 10.1002/wene.325

Ahmed, S., Bryant, L. D., Tizro, Z., and Shickle, D. (2012). Interpretations of informed choice in antenatal screening: a cross-cultural, Q-methodology study. *Soc. Sci. Med.* 74, 997–1004. doi: 10.1016/j.socscimed.2011.12.021

Akter, S., Rutsaert, P., Luis, J., Htwe, N. M., San, S. S., Raharjo, B., et al. (2017). Women's empowerment and gender equity in agriculture: a different perspective from Southeast Asia. *Food Policy* 69, 270–279. doi: 10.1016/j.foodpol.2017.05.003

Alexander, K. S., Greenhalgh, G., Moglia, M., Thephavanh, M., Sinavong, P., Larson, S., et al. (2020). What is technology adoption? Exploring the agricultural research value chain for smallholder farmers in Lao PDR. *Agric. Hum. Values* 37, 17–32. doi: 10.1007/s10460-019-09957-8

Ali, A., Bahadur Rahut, D., and Behera, B. (2016). Factors influencing farmers? adoption of energy-based water pumps and impacts on crop productivity and household income in Pakistan. *Renew. Sustain. Energy Rev.* 54, 48–57. doi: 10.1016/j.rser.2015.09.073

Annarelli, A., Battistella, C., and Nonino, F. (2016). Product service system: a conceptual framework from a systematic review. *J. Clean. Prod.* 139, 1011–1032. doi: 10.1016/j.jclepro.2016.08.061

aQysta (2018a). *aQysta: Innovating for Impact. aQysta Innov. Impact*. Available online at: https://www.aqysta.com/ (accessed August 14, 2020).

aQysta (2018b). *Barsha Pump. aQysta Innov. Impact*. Available online at: https://www.aqysta.com/products/barsha-pump/ (accessed August 14, 2020).

aQysta (2022). *Our Story. aQysta*. Available online at: https://www.aqysta.com/our-story/ (accessed May 11, 2022).

Banasick, S. (2019). KADE: a desktop application for Q methodology. *J. Open Source Softw.* 4, 1360. doi: 10.21105/joss.01360

Banasick, S. (2020). *Easy HtmlQ. GitHub*. Available online at: https://github.com/shawnbanasick/easy-htmlq (accessed July 25, 2020).

Bastakoti, R., Raut, M., and Thapa, B. R. (2020). *Groundwater Governance and Adoption of Solar-Powered Irrigation Pumps: Experiences from the Eastern Gangetic Plains*. Washington, DC: iWMI. Available online at: http://hdl.handle.net/10986/33245 (accessed September 7, 2020).

Buil, I., de Chernatony, L., and Martínez, E. (2012). Methodological issues in cross-cultural research: an overview and recommendations. *J. Targeting, Meas. Anal. Mark.* 20, 223–234. doi: 10.1057/jt.2012.18

Burney, J. A., and Naylor, R. L. (2012). Smallholder irrigation as a poverty alleviation tool in Sub-Saharan Africa. *World Dev.* 40, 110–123. doi: 10.1016/j.worlddev.2011.05.007

Cammelli, F., Coudel, E., and de Freitas Navegantes Alves, L. (2019). Smallholders' perceptions of fire in the Brazilian Amazon: exploring implications for governance arrangements. *Hum. Ecol.* 47, 601–612. doi: 10.1007/s10745-019-00096-6

Chamberlain, W. O., and Anseeuw, W. (2019). Inclusiveness revisited: assessing inclusive businesses in South African agriculture. *Dev. South. Afr.* 36, 600–615. doi: 10.1080/0376835X.2018.1518708

Chambers, R. (2017). *Can we Know Better?* Reflections for Development. Rugby, UK: Practical Action Publishing. doi: 10.3362/9781780449449.000

Cherry, C., and Pidgeon, N. (2018). Why is ownership an issue? Exploring factors that determine public acceptance of product-service systems. *Sustainability* 10, 2289. doi: 10.3390/su10072289

Chuchird, R., Sasaki, N., and Abe, I. (2017). Influencing factors of the adoption of agricultural irrigation technologies and the economic returns: a case study in Chaiyaphum Province, Thailand. *Sustainability* 9, 1524. doi: 10.3390/su9091524

Cuppen, E. H. W. J. (2010). *Putting Perspectives into Participation: Constructive Conflict Methodology for Problem Structuring in Stakeholder Dialogues*. Oisterwijk, The Netherlands: Uitgeverij BOXPress. Available online at: https://research.vu.nl/en/publications/putting-perspectives-into-participation-constructive-conflict-met (accessed July 20, 2020).

Curry, G. N., Nake, S., Koczberski, G., Oswald, M., Rafflegeau, S., Lummani, J., et al. (2021). Disruptive innovation in agriculture: socio-cultural factors in technology adoption in the developing world. *J. Rural Stud.* 88, 422–431. doi: 10.1016/j.jrurstud.2021.07.022

de Brauw, A., and Bulte, E. (2021). "Smallholders and Markets," in *African Farmers, Value Chains and Agricultural Development: An Economic and Institutional Perspective* (Cham, Switzerland: Palgrave Macmillan), 83–107. doi: 10.1007/978-3-030-88693-6_5

de Fraiture, C., and Giordano, M. (2014). Small private irrigation: a thriving but overlooked sector. *Agric. Water Manag.* 131, 167–174. doi: 10.1016/j.agwat.2013.07.005

Demyttenaere, K., Dewit, I., and Jacoby, A. (2016). The influence of ownership on the sustainable use of product-service systems—a literature review. *Procedia CIRP* 47, 180–185. doi: 10.1016/j.procir.2016.03.071

Devkota, R., Pant, L. P., Gartaula, H. N., Patel, K., Gauchan, D., Hambly-Odame, H., et al. (2020). Responsible agricultural mechanization innovation for the sustainable development of Nepal's Hillside farming system. *Sustainability* 12, 374. doi: 10.3390/su12010374

Fan, S., Brzeska, J., Keyzer, M., and Halsema, A. (2013). *From Subsistence to Profit: Transforming Smallholder Farms*. Washington, DC: IFPRI. doi: 10.2499/9780896295582

Fan, S., and Rue, C. (2020). "The Role of Smallholder Farms in a Changing World," in *The Role of Smallholder Farms in Food and Nutrition Security* (Cham: Springer International Publishing), 13–28. doi: 10.1007/978-3-030-42148-9_2

FAO (2017). *The Future of Food and Agriculture—Trends and Challenges*. Rome, Italy Available online at: http://www.fao.org/publications/fofa/en/

FAO (2019). *The State of Food Security and Nutrition in the World 2019*. FAO. Available online at: http://www.fao.org/state-of-food-security-nutrition (accessed August 21, 2020).

Foguesatto, C. R., Borges, J. A. R., and Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. *Sci. Total Environ.* 729, 138831. doi: 10.1016/j.scitotenv.2020.138831

Fraenkel, P., and Thake, J. (2006). *Water Lifting Devices: A Handbook for Users and Choosers*. Rugby: Practical Action Publishing. doi: 10.3362/9781780446370.000

GC, R. K., and Hall, R. P. (2020). The commercialization of smallholder farming—a case study from the rural western middle hills of Nepal. *Agriculture* 10, 143. doi: 10.3390/agriculture10050143

Gebregziabher, G., Giordano, M. A., J, S. L., and Namara, R. E. (2014). Economic analysis of factors influencing adoption of motor pumps in Ethiopia. *J. Dev. Agric. Econ.* 6, 490–500. doi: 10.5897/JDAE2014.0576

German, L. A., Bonanno, A. M., Foster, L. C., and Cotula, L. (2020). "Inclusive business" in agriculture: evidence from the evolution of agricultural value chains. *World Dev.* 134, 105018. doi: 10.1016/j.worlddev.2020.105018

Getacher, T., Mesfin, A., and Gebre-Egziabher, G. (2013). Adoption and impacts of an irrigation technology: Evidence from household level data in Tigray, Northern Ethiopia. *African J. Agric. Res.* 8, 4766–4772.

Giordano, M., Barron, J., and Ünver, O. (2019). "Water scarcity and challenges for smallholder agriculture," in *Sustainable Food and Agriculture* (Rome: FAO and Elsevier), 75–94. doi: 10.1016/B978-0-12-812134-4.00005-4

Glover, D., Sumberg, J., Ton, G., Andersson, J., and Badstue, L. (2019). Rethinking technological change in smallholder agriculture. *Outlook Agric.* 48, 169–180. doi: 10.1177/0030727019864978

Glover, D., Venot, J.-P., and Maat, H. (2017). "On the movement of agricultural technologies: Packaging, unpacking and situated reconfiguration," in *Agronomy for Development: The Politics of Knowledge in Agricultural Research*, ed. S. James (London: Routledge), 14–30. doi: 10.4324/9781315284057-2

Gopal, C., Mohanraj, M., Chandramohan, P., and Chandrasekar, P. (2013). Renewable energy source water pumping systems—a literature review. *Renew. Sustain. Energy Rev.* 25, 351–370. doi: 10.1016/j.rser.2013.04.012

Gupta, E. (2019). The impact of solar water pumps on energy-water-food nexus: evidence from Rajasthan, India. *Energy Policy* 129, 598–609. doi: 10.1016/j.enpol.2019.02.008

Gurung, A., Karki, R., Cho, J. S., Park, K. W., and Oh, S.-E. (2013). Roles of renewable energy technologies in improving the rural energy situation in Nepal: gaps and opportunities. *Energy Policy* 62, 1104–1109. doi: 10.1016/j.enpol.2013.06.097

Hu, Y., You, F., and Luo, Q. (2018). Characterizing the attitudes of the grain-planting farmers of Huaihe Basin, China. *Food Policy* 79, 224–234. doi: 10.1016/j.foodpol.2018.07.007

Hugé, J., Vande Velde, K., Benitez-Capistros, F., Japay, J. H., Satyanarayana, B., Nazrin Ishak, M., et al. (2016). Mapping discourses using Q methodology in Matang Mangrove Forest, Malaysia. *J. Environ. Manag.* 183, 988–997. doi: 10.1016/j.jenvman.2016.09.046

Indrayanti, K. W., and Mochtar, D. A. (2021). Evaluating the policy and program on gender mainstreaming through the role of woman farmer group in easi pay barsha pump program in Waingapu Sumba, Indonesia. in *Proceedings of the 1st International Conference on Research in Social Sciences and Humanities (ICoRSH 2020)* (South Tangerang: Atlantis Press SARL), 659–663.

Intriago Zambrano, J. C. (2020). *Replication Data for: Smallholders' Discourses on the Adoption of the Barsha Pump: A Q Methodology Study in Nepal and Indonesia, as part of the DARE-TU PhD project*. DataverseNL. Available online at: https://doi.org/10.34894/AURC5E (accessed October 17, 2022).

Intriago Zambrano, J. C., Michavila, J., Arenas Pinilla, E., Diehl, J. C., and Ertsen, M. W. (2019). Water lifting water: a comprehensive spatiotemporal review on the hydro-powered water pumping technologies. *Water* 11, 1677. doi: 10.3390/w11081677

Intriago, J. C., Ertsen, M., Diehl, J.-C., Michavila, J., and Arenas, E. (2018). Co-creation of affordable irrigation technology: the DARE-TU project. in *International Conference Water Science for Impact* (Wageningen, The Netherlands), 1. Available online at: https://repository.tudelft.nl/islandora/object/uuid%3Af512eafc-0b22-4c7f-9d3e-41d17377a88e?collection=research (accessed February 22, 2019).

Khatiwada, D. (2020). Why agricultural subsidies have failed to benefit needy farmers. *Kathmandu Post*. Available online at: https://kathmandupost.com/money/2020/02/20/why-agricultural-subsidies-have-failed-to-benefit-needy-farmers (Accessed September 22, 2020).

Kyriakarakos, G., Balafoutis, A. T., and Bochtis, D. (2020). Proposing a paradigm shift in rural electrification investments in sub-saharan africa through agriculture. *Sustainability* 12, 3096. doi: 10.3390/su12083096

Llewellyn, R. S., and Brown, B. (2020). Predicting adoption of innovations by farmers: What is different in smallholder agriculture? *Appl. Econ. Perspect. Policy* 42, 100–112. doi: 10.1002/aepp.13012

Montes de Oca Munguia, O., and Llewellyn, R. (2020). The adopters versus the technology: Which matters more when predicting or explaining adoption? *Appl. Econ. Perspect. Policy* 42, 80–91. doi: 10.1002/aepp.13007

Mottaleb, K. A. (2018). Perception and adoption of a new agricultural technology: evidence from a developing country. *Technol. Soc.* 55, 126–135. doi: 10.1016/j.techsoc.2018.07.007

Mottaleb, K. A., Krupnik, T. J., and Erenstein, O. (2016). Factors associated with small-scale agricultural machinery adoption in Bangladesh: census findings. *J. Rural Stud.* 46, 155–168. doi: 10.1016/j.jrurstud.2016.06.012

Namara, R. E., Hope, L., Sarpong, E. O., De Fraiture, C., and Owusu, D. (2014). Adoption patterns and constraints pertaining to small-scale water lifting technologies in Ghana. *Agric. Water Manag.* 131, 194–203. doi: 10.1016/j.agwat.2013.08.023

Nederstigt, J., and Bom, G. J. (2014). *Renewable Energy for Smallholder Irrigation: A Desk Study on the Current State and Future Potential of Using Renewable Energy Sources for Irrigation By Smallholder Farmers*. Ouagadougou. Available online at: https://www.practica.org/wp-content/uploads/2014/10/Renewable_Energy_for_Smallholder_Irrigation.pdf (accessed September 7, 2020).

Nordhagen, S., Pascual, U., and Drucker, A. G. (2017). Feeding the household, growing the business, or just showing off? Farmers' motivations for crop diversity choices in Papua New Guinea. *Ecol. Econ.* 137, 99–109. doi: 10.1016/j.ecolecon.2017.02.025

Nugrohowardhani, R. L. K. R. (2014). Women's resistance in cotton industry: study on environmental degradation in East Sumba. *Indones. Fem. J.* 2, 106–129. Available online at: https://www.jurnalperempuan.org/indonesian-feminist-journal.html.

NWO (2020). *Enabling Access to Sustainable Irrigation: Pay-per-harvest Irrigation Service for Barsha Pumps in Indonesia (EASI-Pay)*. NWO. Available online at: https://www.nwo.nl/en/research-and-results/research-projects/i/40/27640.html (accessed September 7, 2020).

Olum, S., Gellynck, X., Juvinal, J., Ongeng, D., and De Steur, H. (2020). Farmers' adoption of agricultural innovations: A systematic review on willingness to pay studies. *Outlook Agric.* 49, 187–203. doi: 10.1177/0030727019879453

Omary, M. B., Eswaraka, J., Kimball, S. D., Moghe, P. V., Panettieri, R. A., and Scotto, K. W. (2020). The COVID-19 pandemic and research shutdown: staying safe and productive. *J. Clin. Invest.* 130, 2745–2748. doi: 10.1172/JCI138646

Paudel, G. P., Gartaula, H., Rahut, D. B., and Craufurd, P. (2020). Gender differentiated small-scale farm mechanization in Nepal hills: An application of exogenous switching treatment regression. *Technol. Soc.* 61, 101250. doi: 10.1016/j.techsoc.2020.101250

Paudel, G. P., KC, D. B., Rahut, D. B., Justice, S. E., and McDonald, A. J. (2019a). Scale-appropriate mechanization impacts on productivity among smallholders: evidence from rice systems in the mid-hills of Nepal. *Land use policy* 85, 104–113. doi: 10.1016/j.landusepol.2019.03.030

Paudel, G. P., KC, D. B., Rahut, D. B., Khanal, N. P., Justice, S. E., and McDonald, A. J. (2019b). Smallholder farmers' willingness to pay for scale-appropriate farm mechanization: Evidence from the mid-hills of Nepal. *Technol. Soc.* 59, 101196. doi: 10.1016/j.techsoc.2019.101196

Poole, N. (2017). *Smallholder Agriculture and Market Participation*. Rugby: Practical Action Publishing. doi: 10.3362/9781780449401.000

Poudyal, R., Loskot, P., Nepal, R., Parajuli, R., and Khadka, S. K. (2019). Mitigating the current energy crisis in Nepal with renewable energy sources. *Renew. Sustain. Energy Rev.* 116, 109388. doi: 10.1016/j.rser.2019.109388

Ritchie, H., and Roser, M. (2020). *Agricultural Production*. Our World Data. Available online at: https://ourworldindata.org/agricultural-production (accessed August 21, 2020).

Robbins, P. (2005). "Q Methodology," in *Encyclopedia of Social Measurement*, ed. K. Kempf-Leonard (Amsterdam: Elsevier), 209–215. doi: 10.1016/B0-12-369398-5/00356-X

Roka, H. (2017). The Status of smallholder farmers in Nepal's agricultural development strategy (2015–2035). *Agrar. South J. Polit. Econ.* 6, 354–372. doi: 10.1177/2277976017745197

Rola-Rubzen, M. F., Paris, T., Hawkins, J., and Sapkota, B. (2020). Improving gender participation in agricultural technology adoption in Asia: from rhetoric to practical action. *Appl. Econ. Perspect. Policy* 42, 113–125. doi: 10.1002/aepp.13011

Röling, N. (2009). Pathways for impact: scientists' different perspectives on agricultural innovation. *Int. J. Agric. Sustain.* 7, 83–94. doi: 10.3763/ijas.2009.0043

Roser, M., and Ritchie, H. (2013). *Hunger and Undernourishment*. Our World Data. Available online at: https://ourworldindata.org/hunger-and-undernourishment (accessed August 21, 2020).

Roser, M., Ritchie, H., and Ortiz-Ospina, E. (2013). *World Population Growth*. Our World Data. Available online at: https://ourworldindata.org/world-population-growth (accessed August 21, 2020).

Ruben, R., and Pender, J. (2004). Rural diversity and heterogeneity in less-favoured areas: the quest for policy targeting. *Food Policy* 29, 303–320. doi: 10.1016/j.foodpol.2004.07.004

Samberg, L. H., Gerber, J. S., Ramankutty, N., Herrero, M., and West, P. C. (2016). Subnational distribution of average farm size and smallholder contributions to global food production. *Environ. Res. Lett.* 11, 124010. doi: 10.1088/1748-9326/11/12/124010

Schneider, C., Coudel, E., Cammelli, F., and Sablayrolles, P. (2015). Small-scale farmers' needs to end deforestation: insights for REDD+ in São Felix do Xingu (Pará, Brazil). *Int. For. Rev.* 17, 124–142. doi: 10.1505/146554815814668963

Senapati, A. K. (2020). Evaluation of risk preferences and coping strategies to manage with various agricultural risks: evidence from India. *Heliyon* 6, e03503. doi: 10.1016/j.heliyon.2020.e03503

Shah, T., Rajan, A., Rai, G. P., Verma, S., and Durga, N. (2018). Solar pumps and South Asia's energy-groundwater nexus: exploring implications and reimagining its future. *Environ. Res. Lett.* 13, 115003. doi: 10.1088/1748-9326/aae53f

Sims, B., and Kienzle, J. (2017). Sustainable agricultural mechanization for smallholders: What is it and how can we implement it? *Agriculture* 7, 50. doi: 10.3390/agriculture7060050

Slavchevska, V., Kaaria, S., and Taivalmaa, S. L. (2019). "The Feminization of Agriculture," in *The Oxford Handbook of Food, Water and Society*, eds. T. Allan, B. Bromwich, M. Keulertz, and A. Colman (New York, NY: Oxford University Press), 267–284. doi: 10.1093/oxfordhb/9780190669799.013.55

Stenner, P., and Rogers, R. S. (2004). "Q methodology and qualiquantology: the example of discriminating between emotions," in *Mixing Methods in Psychology: The Integration of Qualitative and Quantitative Methods in Theory and Practice*, eds. Z. Todd, B. Nerlich, S. McKeown, and D. D. Clarke (London: Psychology Press), 99–118.

Stephenson, W. (1935). Technique of factor analysis. *Nature* 136, 297. doi: 10.1038/136297b0

Stone, T. E., Maguire, J., Kang, S. J., and Cha, C. (2017). Practical issues of conducting a Q methodology study: lessons learned from a cross-cultural study. *Adv. Nurs. Sci.* 40, 291–299. doi: 10.1097/ANS.0000000000000164

Sudgen, F., Agarwal, B., Leder, S., Saikia, P., Raut, M., Kumar, A., et al. (2020). Experiments in farmers' collectives in Eastern India and Nepal: process, benefits, and challenges. *J. Agrar. Chang.* 21, 12369. doi: 10.1111/joac.12369

Taras, V., Steel, P., and Kirkman, B. L. (2016). does country equate with culture? Beyond geography in the search for cultural boundaries. *Manag. Int. Rev.* 56, 455–487. doi: 10.1007/s11575-016-0283-x

ten Klooster, P. M., Visser, M., and de Jong, M. D. T. (2008). Comparing two image research instruments: the Q-sort method versus the Likert attitude questionnaire. *Food Qual. Prefer.* 19, 511–518. doi: 10.1016/j.foodqual.2008.02.007

Theis, S., Lefore, N., Meinzen-Dick, R., and Bryan, E. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agric. Hum. Values* 35, 671–684. doi: 10.1007/s10460-018-9862-8

Truong, D. B., Binot, A., Peyre, M., Nguyen, N. H., Bertagnoli, S., and Goutard, F. L. (2017). A Q method approach to evaluating farmers' perceptions of foot-and-mouth disease vaccination in Vietnam. *Front. Vet. Sci.* 4, 1–12. doi: 10.3389/fvets.2017.00095

Truong, D. B., Doan, H. P., Doan Tran, V. K., Nguyen, V. C., Bach, T. K., Rueanghiran, C., et al. (2019). Assessment of drivers of antimicrobial usage in poultry farms in the mekong delta of vietnam: a combined participatory epidemiology and Q-sorting approach. *Front. Vet. Sci.* 6, 1–11. doi: 10.3389/fvets.2019.00084

United Nations (2020a). Goal 2: zero hunger. *Sustain. Dev. Goals*. Available online at: https://www.un.org/sustainabledevelopment/hunger/ (accessed August 12, 2020).

United Nations (2020b). *World Economic Situation and Prospects 2020*. New York, NY, USA. Available online at: https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects-2020/ (accessed July 20, 2020).

Van Loon, J., Woltering, L., Krupnik, T. J., Baudron, F., Boa, M., and Govaerts, B. (2020). Scaling agricultural mechanization services in smallholder farming systems: case studies from sub-Saharan Africa, South Asia, and Latin America. *Agric. Syst.* 180, 102792. doi: 10.1016/j.agsy.2020.102792

Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J., Masso, C., et al. (2014). Sustainable intensification and the African smallholder farmer. *Curr. Opin. Environ. Sustain.* 8, 15–22. doi: 10.1016/j.cosust.2014.06.001

Vargas, A., Diaz, D., and Aldana-Domínguez, J. (2019). Public discourses on conservation and development in a rural community in Colombia: an application of Q-methodology. *Biodivers. Conserv.* 28, 155–169. doi: 10.1007/s10531-018-1644-5

Vel, J. A. C. (2008). *Uma Politics: An Ethnography of Democratization in West Sumba, Indonesia, 1986–2006*. Leiden, The Netherlands: KITLV Press. doi: 10.26530/OAPEN_393150

Vel, J. A. C., and Makambombu, S. (2009). *Access in Land Disputes Arising in the Context of the Commercialization of Agriculture in Sumba* (*Nusa Tenggara Timur*). Leiden. Available online at: https://openaccess.leidenuniv.nl/handle/1887/18311 (accessed September 7, 2020).

Vel, J. A. C., and Makambombu, S. (2010). Access to agrarian justice in Sumba, Eastern Indonesia. *Law, Soc. Justice Glob. Dev. J.* 15, 1–22. Available online at: https://warwick.ac.uk/fac/soc/law/elj/lgd/2010_1/vel_makambombu (accessed September 7, 2020).

Villarreal, M. (2022). "Can hunger be eradicated by 2030?," in *SOStenibilità—Tre lezioni sull'Agenda 2030* (Rome, Italy: RomaTrE-Press), 15–35. Available online at: https://romatrepress.uniroma3.it/en/libro/sostenibilita-tre-lezioni-sullagenda-2030/ (accessed September 16, 2020).

Watts, S., and Stenner, P. (2005a). Doing Q methodology: theory, method and interpretation. *Qual. Res. Psychol.* 2, 67–91. doi: 10.1191/1478088705qp022oa

Watts, S., and Stenner, P. (2005b). The subjective experience of partnership love: a Q methodological study. *Br. J. Soc. Psychol.* 44, 85–107. doi: 10.1348/014466604X23473

Watts, S., and Stenner, P. (2012). *Doing Q Methodological Research: Theory, Method and Interpretation*. 1. London: SAGE Publications Ltd. doi: 10.4135/9781446251911

Weldegiorgis, F. S., and Ali, S. H. (2016). Mineral resources and localised development: Q-methodology for rapid assessment of socioeconomic impacts in Rwanda. *Resour. Policy* 49, 1–11. doi: 10.1016/j.resourpol.2016.03.006

Woltering, L., Fehlenberg, K., Gerard, B., Ubels, J., and Cooley, L. (2019). Scaling—from "reaching many" to sustainable systems change at scale: a critical shift in mindset. *Agric. Syst.* 176, 102652. doi: 10.1016/j.agsy.2019.102652

Wong, S. (2019). "Decentralised, off-grid solar pump irrigation systems in developing countries—are they pro-poor, pro-environment and pro-women?," in *Climate Change-Resilient Agriculture and Agroforestry*, eds. P. Castro, A. M. Azul, W. L. Filho, and U. M. Azeiteiro (Springer), 367–382. doi: 10.1007/978-3-319-75004-0_21

Yoshizawa, G., Iwase, M., Okumoto, M., Tahara, K., and Takahashi, S. (2016). Q workshop: an application of Q methodology for visualizing, deliberating and learning contrasting perspectives. *Int. J. Environ. Sci. Educ.* 11, 6277–6302. Available online at: http://www.ijese.net/makale/795.html (accessed September 7, 2020).

Zhou, D., and Abdullah (2017). The acceptance of solar water pump technology among rural farmers of northern Pakistan: a structural equation model. *Cogent Food Agric.* 3, 1–17. doi: 10.1080/23311932.2017.1280882

Ziegler, J. H. (1766). "Vorläufige Anzeige eines neuen Schöpfrades [Preliminary display of a new bucket wheel]," in *Abhandlungen der Naturforschenden Gesellschaft in Zürich [Treatises of the Nature Research Society in Zurich]* (Zurich, Switzerland), 431–463. Available online at: https://archive.org/stream/abhandlungendern03natu#page/n447/mode/2up (accessed August 27, 2020).