Manuscript prepared for J. Name
with version 2014/09/16 7.15 Copernicus papers of the LaTeX class copernicus.cls.
Date: 1 December 2015

The use of Semi-Structured Interviews for the Characterisation of Farmer Irrigation Practices

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Abstract. Generating information on the behaviours, characteristics and drivers of users, as well on the resource itself, is vital in developing sustainable and realistic water security options. In this paper we present a methodology for collecting qualitative and quantitative data on water use practices through semi-structured interviews. This approach facilitates the collection of detailed information on actors' decisions in a convenient and cost-effective manner. The interview is organised around a topic guide, which helps lead the conversation in a standardised way while allowing sufficient opportunity for relevant issues to emerge. In addition, semi-structured interviews can be used to obtain certain types of quantitative data. While not as accurate as direct measurements, it can provide useful information on local practices and users' insights. We present an application of the methodology on farmer water use on two districts in the State of Uttar Pradesh in North India. By means of 100 farmer interviews, information was collected on various aspects of irrigation practices, including irrigation water volumes, irrigation cost, water source and their spatial variability. A statistical analysis of the information, along with some data visualisation is also presented, which highlights a significant variation in irrigation practices both within and between the districts. In addition, some of the perceptions and experiences of farmers, in particular those related to water use, are explored. Our application shows that semi-structured interviews are an effective and efficient method of collecting both qualitative and quantitative information for the assessment of drivers, behaviours and their outcomes in a data scarce region. The collection of this type of data could significantly improve insight on water resources, leading to more realistic management options and increased water security in the future.

1 INTRODUCTION

The interactions between humans and water resources are often poorly understood; an issue which can be reflected in the decisions behind water resource planning. While some anthropogenic influences, such as greenhouse gas emissions and land use change, have been incorporated in much of the current modelling and decision making framework, less work has been done on the human - water interface (Nazemi and Wheater, 2015a). This shortfall is seen as a major challenge in Earth System Modelling (GEWEX, 2012) and consequently decisions on water resource management. Given that human induced issues of water scarcity affect many parts of the world (Döll et al., 2014; Famiglietti, 2014; Rodell et al., 2009; Voss et al., 2013; Wada et al., 2010), there is a need to understand anthropogenic–hydrological linkages in order to better manage water resources in the future. Socio-hydrology provides a means of supporting sustainable societal development in a changing environment Montanari (2015). Indeed, the significance of including so-called soft data has been well documented (see Siebert and Döll (2010), Fenicia et al. (2011)). Winsemius et al. (2009) argues the importance of including qualitative information to improve model realism, and while this may lead to reduced model efficiency, it can help produce a more realistic representation of catchment behaviour. Making use of this "experimental common sense" (Döll and Siebert, 2002) is an important step in more accurately representing anthropogenic water use in models and while this paper is primarily concerned with data collection, the importance of obtaining and using soft, qualitative data is implied. Globally, irrigation water consumption accounts for some 70% of total groundwater and surface water withdrawals (Wisser et al., 2008). This figure has increased dramatically over the last sixty years, largely as a result of population growth, market expansion and technological advances in water abstraction. Consequently irrigation water use needs to be explored in more detail than non-irrigative demand (Nazemi and Wheater, 2015a).

Representing water use however presents many challenges, much of which stem from a lack of data (Gao et al., 2012; Portmann et al., 2010; Nazemi and Wheater, 2015b). This often leads to oversimplification, either in resolution Döll and Siebert (2002) or in user behaviour, which can subsequently be reflected in model outputs. For example, irrigation water requirements are often calculated based on the ideal crop water requirement (see Allen et al. (1998) and McKenney and Rosenberg (1993)) giving a false representation of what is actually taking place on the ground, as users will often over or under irrigate depending on prevailing social, economic or environmental conditions. Large scale model outputs or data representations also provide excellent tools for examining water use or resource trends Döll and Siebert (2002); Rodell et al. (2009). While such approaches are useful as an overview of large scale issues, they are inadequate for developing realistic solutions at any meaningful implementable level. The data collection methods described in this paper are aimed at providing information for more local scale models and decision making, particularly in instances where such information is scarce. This dearth of information includes both quantitative and qualitative data. In order to come up with suitable options for the use of water, it is important to generate

information at a realistic spatial resolution, not only on the water resource itself, but also on the behaviours, characteristics and drivers of its managers and users.

In social sciences and healthcare the collection of both qualitative and quantitative information through interviews is relatively common practice (Barriball and While, 1994; Ellis and Chen, 2013; Fallon, 2008; Gibson, 1998)), however such methods are less used in the fields of earth and engineering sciences. For the purposes of data collection for hydrological studies little guidance exists. In both a time and resource constrained setting the use of semi-structured interviews provides an efficient and effective method for qualitative and quantitative data collection. This is particularly true of data scarce regions, as in our case study, where little field information exists. According to Calheiros et al. (2000), using an ethnographic methodology is useful in instances where the theory is incomplete, the phenomena are observable and important at a local level. For the most part little room exists for the inclusion of "non-experts" into the application of scientific research methods Calheiros et al. (2000). The incorporation of local knowledge however can have many advantages, including better defining the research questions and raising locally important, as well as unimportant, factors. Unlike a structured interview which contains a series of set questions asked the same way to all interviewees, a semi-structured interview is organised around a topic guide. The topic guide ensures the main points of interest are satisfied during the interview Mason (2002), while still allowing the overall direction to be shaped by the participants own understanding, so called experiential or traditional knowledge, of their environment. This naturally highlights issues which are of most importance to the interviewee and allows room to incorporate new themes. Semi-structured interviews can quickly produce rich and detailed data sets Fallon (2008) offering an accurate assessment of the characteristics of individuals and phenomena. Importantly it can also shed light on the drivers of these events and the motivations behind user decisions, providing a valuable contribution to earth systems modelling. Semi-structured interviews allow for the collection of qualitative and quantitative information efficiently and cheaply, in an unobtrusive and open manner. While qualitative approaches such as semi-structured interviews are widely recognised and regularly applied by social scientists working on water resources, they are scarcely used by natural scientists in the context of hydrology and modelling. In this paper we show how the method can be used for hydrological research, however, we see much greater scope for interdisciplinary dialogue on semi-structured interviews and its broader relevance in addressing hydrological model uncertainties. Aspects of the approach reported herein may differ from traditional methods (see Burnard et al. (2008), Creswell (2009)), for example in terms of sampling. However, we believe semi-structured interviews provide a potent tool for data collection on water use. In this study, we applied this approach to two districts in the Northern Indian State of Uttar Pradesh to study irrigation water use and the results will be presented as a case study in section 3, with the methodology used described in section 2.

2 METHODOLOGY

2.1 Study preparation and interview design

The collection of qualitative and quantitative data in the field requires an understanding of the relevant existing published research, as well as the social nuances which exist in a study region. This knowledge is essential in the planning phase, including in the design of the topic guide, around which the semi-structured interview is based (Ellis and Chen, 2013). The literature review and pre-fieldwork planning, which should also take practicalities such as logistics and cost into account, help define the main study area and target interview participants. In this paper we treat the semi-structured interview purely as a tool for the collection of hydrological data in the field. Careful and consistent phrasing of questions in the interview is important and draws on the pre-field work research as well as knowledge of the local characteristics. Questions should be unambiguous and easily understood by interviewees, related to their own experiences, ethically and culturally sensitive and ensure that they assist, rather than impede, the flow of information. In addition, the interviewer must ensure that the questions provide data which will address the research questions appropriately (Mason, 2002). Interviewees may not be able to give a direct answer to a technical question, however, skilfully crafted component questions can be combined to produce the required information (e.g abstraction rates achieved via depth of water applied and irrigated area).

A significant advantage of semi-structured interviews is the opportunity for previously unknown information to emerge. This can occur when the interviewee is allowed sufficient opportunity to speak freely which, by making use of the fact that participant's are experts by experience, may result in the emergence of new and novel information. This approach allows both quantitative and qualitative data extraction, for example the volume of water a farmer takes from a particular source and their reason for this. This approach can yield considerable benefits in terms of cost whilst ensuring a useful representation of parameters. Semi-structured interviews are traditionally comprised of open-ended questions. The collection of quantitative data however is best obtained through direct questions. For this reason the topic guide contains both. The topic guide used in the case study interviews contains both open-ended and direct questions (can be seen in the supplementary information accompanying this paper). While acquiring quantitative information in this manner is not as accurate as metered data for example, we believe this approach can provide a useful representation of the important parameters and has a place in situations where other measures could be considered unacceptable, or unfeasible in the environment.

2.2 Sampling

Sampling comprises an integral part of study design. It allows us to select cases from a wider population, too big to be studied completely, enabling us to generalise the final research conclusions to an entire population, not just to the individual participants of a study (Flick, 2014). This is an important

consideration when collecting information which could be used in policy as any decisions arising from this data should be as applicable to as many people as possible. The sampling procedure traditionally adopted with semi-structured interviews does not aim to achieve a representative sample. However, it is felt that seeking a representative sample was a useful strategy for the purpose of the case study reported herein, in order to produce more universally applicable results. This is achieved through a combination of sampling techniques. For example, purposive sampling provides a useful starting point by selecting participants which are thought to be information rich. Purposive sampling allows subjects to be selected based on their characteristics, and while this approach is often used to highlight and study extreme or deviant cases, it can allow the researcher to target sample populations which are likely to provide information of most relevance to the research questions. Once a sample group has been identified randomisation should take place to ensure a representative cross section of the study group is achieved. Prior to undertaking fieldwork it is necessary to set participant inclusion and exclusion criteria as it is likely that potential interviewees who fall outside the research area interests will be approached. Inclusion and exclusion criteria also help promote the best use of available resources.

2.3 Conducting the Interview

Introducing the study to potential participants is essential in order to gain informed consent. This involves a clear and concise explanation of the purpose of the research, what the interview will involve and how you are going to use and store the information collected. It should also be highlighted that the respondent is under no obligation to answer any of the questions if they do not wish to (Mottram, 2011). This component of the research is important not only in creating the right kind of environment where the interviewee feels they can provide the information, but also in building good rapport with the individual (Rabionet, 2011). The subject of ethics is an important consideration when entering other peoples environments and collecting data on their livelihoods. While it is outside the scope of this paper to provide guidelines on ethics, it is strongly recommended that they are taken into account during the planning stage of the study.

Interviews may need to be carried via translator(s), and pre-project training should be provided beforehand to ensure consistency in terms of interview style. In the field, interviews may be conducted in the presence of family members or neighbours. While for practical and cultural reasons it may not be possible to avoid this, care should be taken at all times to address the question to and receive the response from the designated participant, bearing in mind the potential impact others' presence may have on the answers received. It is important that the interview is recorded in as much detail as possible, ideally through a mixture of field notes and a voice recorder. Again, consent should be sought from the interview participant prior to the recording of any conversation. GPS readings of where the interview takes place and any other pertinent locations, for example wells or canal access points, should also be taken, along with photos and samples where applicable. Data should be stored

safely and securely following all applicable institutional guidelines. It should be made clear to the participants that their privacy and confidentiality will be maintained to the highest degree possible.

2.4 Data processing and analyses

Following the collection of data, all interviews should be transcribed verbatim. While time consuming, a full transcription is paramount in avoiding bias introduced through selective data extraction by the researcher, who may have particular themes or research questions in mind. It also ensures that all data remains available for further analyses, rather than what is of interest to the researcher at that time. Reading the transcripts results in various themes emerging from the text. From this a thematic analysis begins. These themes are referred to as codes during the analysis. As the analysis progresses, commonality of codes across interviews may become apparent. However, thematic analysis allows new themes or ideas to constantly emerge. The use of qualitative data analysis software, for example RQDA (Huang, 2014) provides a useful platform for processing large amounts of qualitative data. Here, words or sections from a discussion are coded, allowing the frequency and relationships across topics to be analysed (Barnes et al., 2013). While the analysis of textual data can be a difficult process, it is made more straightforward using the appropriate software. It is also important to note that that such tools do not analyse the data, which is the task of the researcher, they only make the handling of such data more straightforward (Burnard et al., 2008). Software also allows information, both qualitative and quantitative, on each theme to be recalled easily. Once the data has been coded, the dominant themes can be identified. Overviews on the distributions of the variables within the database can also be produced. A significant portion of the data collected may also be quantitative and suitable for some statistical analyses and modelling purposes.

3 CASE STUDY - DATA COLLECTION

3.1 Study region: the Ganges Basin, North India

The 'Green Revolution' has led to enormous gains in agricultural productivity in India, largely through the use of more reliable seeds and improved irrigation technology (Singh, 2000). This has allowed India to become food self-sufficient (Jewitt and Baker, 2007) and has undoubtedly improved life for the majority of rural poor. The Indian green revolution has also received much criticism for its environmental and socio-economic impacts. This includes a reduction in India's water resources while becoming one of the most intensely irrigated areas of the world (Rodell et al. (2009), Tiwari et al. (2009), Mueller et al. (2012)). However, to correctly investigate water security, field studies and an understanding of the often highly localised spatial variations in water abstraction need to be considered. While the large scale impacts on water resources are known, the factors influencing irrigation practices on a local level are much less well understood. In order to develop realistic and

socially acceptable options for water use in the future, this local variability needs to be taken into account.

Uttar Pradesh, located on the plains of the Ganges Basin, is the highest producer of food grains and sugarcane in the country (Hagirath et al., 2011) and the most densely populated (Government of India, 2011). Rice, grown during Kharif (the monsoon season from June to October) and wheat during Rabbi (November to April) are the two most dominant crops (Singh et al., 2011). In the past, the dominant irrigation method in Uttar Pradesh has been via canal, much of which is supplied by the Ganges and Yamuna rivers. However according to Amarasinghe et al. (2009), canal irrigation has declined by approximately 40% during the last four decades, with a thirteen fold increase in irrigation by tubewells.

The following sections comprise a description of a case study in which data was collected through a series of semi-structured interviews. This was carried out in a data scarce region, with the collected information, through mapping and statistical analyses, used to gain a better insight into regional irrigation practices and the motivations of users. Based on irrigation water source information contained within the statistical abstract of Uttar Pradesh, Uttar Pradesh State Planning Institute (2012) two districts, Jalaun (highest user of surface water in the State) and Sitapur (one of the highest irrigators in UP using groundwater, the highest was not considered a viable option due to logistical constraints) were chosen for investigation. A map of the study area, along with the interview locations is presented in Figure 1.

3.1.1 Jalaun

Jalaun is located in the south central region of Uttar Pradesh, and is bounded by the Yamuna River to the north and the Betwa River to the east, covering an area of 4,565 km². It is home to over 1.5 million people (Uttar Pradesh State Planning Institute, 2012). Jalaun receives an average annual rainfall of 811 mm, about 70% of which falls during the monsoon season of June to August (ICRISAT-ICAR-IRRI, 2012). Approximately 139,000 hectares of land is irrigated per year using canal water, making it one of the highest users of this resource in the State. While canal water is generally applied through gravity flow along irrigation channels, groundwater is abstracted predominantly using diesel pumps. It was noted that there were approximately 10,421 diesel pump sets recorded in 2012 in the district, with electricity powering just 356 units. As there is no restriction on the number of wells that can be drilled or on pump specifications, it is likely that are many more diesel pumps in use. The main crop grown in the district is wheat; with a total cropped area of 146,307ha. Jalaun is classed as one of Uttar Pradesh's 35 more deprived districts (Ministry of Panchayati Raj, 2014), and is known to be one of the more drought prone regions of the State Avtar et al. (2011).

3.1.2 Sitapur

Sitapur, also considered one of Uttar Pradesh's less developed districts (Ministry of Panchayati Raj, 2014), is located to the north of the state capital Lucknow, and has a population of approximately 4.5 million (Uttar Pradesh State Planning Institute, 2012). The average rainfall in Sitapur is 903 mm, 66% of which falls during the monsoon months (ICRISAT-ICAR-IRRI, 2012). On a district scale it is one of the largest irrigators in Uttar Pradesh and supplies its 374,445 ha of irrigated land largely using groundwater, with canal water only accounting for 17,914 ha. Using electricity for groundwater abstraction in this region is rare, and farmers predominantly use diesel pumps. As with Jalaun, lack of regulations and difficulty in counting wells indicates a larger number of pumps in use across the district. The main crops grown are rice, wheat and sugarcane, with most farmers carrying out a rice-wheat rotation on their land.

3.2 Interview design

The main focus of this study was to investigate farmer irrigation behaviour in the study area and to collect relevant quantitative, as well as qualitative information, all of which may be used for informing and driving models. Following a detailed literature review, a methodology employing semi-structured interviews was designed and a topic guide was organised around the following themes:

1. Farm and Crop information (farm size, soil type crop type, crop calendar, yield)
2. Irrigation Practices (number of irrigation events, irrigation volume, irrigation methods)
3. Water Source (water source reliability, irrigation cost, irrigation method, influences on irrigation, presence of water market, power source, constraints)
4. Other (perceptions of challenges faced, potential rationales, changes in water availability, livelihood sustainability)

The topic guide was designed to collect relevant information with as much flexibility as possible, allowing the interview to be shaped by the interviewees own understandings, the interests of the researcher as well as any unexpected themes that emerge. The topic guide used during the interviews is presented (please see supplementary information). While the contents of the topic guide are presented as questions they were treated as prompts. This allows the conversation to progress with as much flexibility as possible while still keeping the interviews relevant to the research questions. While the aim is to highlight new data through open-ended questions and a fluid interview structure, some direct questions are included, for example relating to farm size or the depth of water.

3.3 Sampling

As described, field work was undertaken in two districts which were chosen based on their irrigation water source, with Jalaun the highest user of canal water in Uttar Pradesh, and Sitapur irrigating

almost exclusively through groundwater. This initial targeted approach was deemed necessary to capture a representative sample of water users, including both conjunctive and groundwater only users producing as rich a data set as possible, whilst also considering logistics and other resource constraints such as time and finances. Following the identification of field work regions, a list of villages in each district was obtained (Government of India, 2011). These were randomized with 15 villages picked as data collection points. Between 3 and 5 interviews were conducted in each of the attended villages, with 50 farmers interviewed in each of the two districts. After approaching a potential interviewee, inclusion and exclusion criteria were used to determine whether or not the participant was suitable. Interview participant inclusion criteria were: (1) A farmer who grew wheat and/or rice, (2) irrigated their crops rather than depended on rain fed only, (3) the farmers land must be within approximately 5km from the village centre and (4) must have the authority to answer the questions. Participants were excluded if they were: (1) too young or did not have the authority to answer the questions, or (2) if their land was too close to a previously interviewed farmer.

3.4 Data collection – conducting the interview

The field work team consisted of the researcher, a translator and a driver. All interviews were conducted through a translator. Potential interviewees were approached when seen in the field. No "gatekeeper", such as a village head or government official was approached in order to facilitate meetings with participants as it was unnecessary, could have impeded the data collection and potentially impacted on the information received. Once a potential participant was identified, they were approached by the researcher and translator, who made an introduction, described the project, and asked if they would be willing to answer questions. It was made clear that the interviewee was under no obligation to take part if they did not wish to, and that all information collected would be treated in the strictest confidence. It was also highlighted that if participants had any questions they were free to ask. During the interview the participant was given as much opportunity as possible to expand on topics that were of most interest to them. All interviews were recorded using a voice recorder and field notes, with GPS readings of pertinent locations and photographs taken throughout.

3.5 Data processing and analyses

Once data collection was completed, all interviews were transcribed verbatim and uploaded to the qualitative data analysis package, RQDA Huang (2014) to allow for thematic analysis of the data. During the interviews and while reading the transcripts, a number of themes emerged as being important to the farmers; for example the cost of irrigation, the reliability of their water source, and the importance of conjunctive surface and groundwater use. These themes were coded to different sections from the transcribed interviews, allowing commonality of themes to emerge across interviews, yet also allowing unique perspectives to be highlighted. A significant portion of the data collected was quantitative. This allowed for statistical analyses of variables to assess differences in irrigation

practices between and within the two districts. These included the volume of water applied (m³/ha), the volume of water required to produce 1 tonne of wheat (m³/t), the cost of wheat irrigation during the growing season (r/ha), the crop yield in tonnes per hectare (t/ha), the farm area (ha) and the cost of irrigation water per cubic meter (rupees/m³). The cost of water in m³ was calculated by taking into account the cost of irrigation and the volume of water applied per hectare. This case study analysis focuses on wheat. While both wheat and rice are grown in Sitapur, rice is not commonly cultivated in Jalaun, with only one farmer out of 50 interviewed growing the crop. The results of the analyses can be found in Figures 2 to 6, with a description of results below.

4 CASE STUDY - DISCUSSION AND RESULTS

4.1 Quantitative results

The results presented in Figure 2 and in the maps in Figures 3 and 4, show there is a significant variance in the irrigation practices of farmers in Jalaun and Sitapur. This can be seen in the volumes of irrigation water used (Figure 2A); with farmers in Sitapur applying on average 1,555 m³/ha more than farmers in Jalaun. This is also reflected in the overall cost of irrigation with farmers in Sitapur paying on average over 7,000 rupees/ha/season more to irrigate their wheat crop than their counterparts in Jalaun (Figure 2B). This is despite the basic cost of water per cubic meter being largely the same; 3.58 r/m³ in Sitapur and 3.84 r/m³ in Jalaun (Figure 2, part F).

Sitapur is by area one of the largest irrigators in Uttar Pradesh, and for the most part uses water from the underlying aquifers. The primary method of abstraction is by diesel pump, which although reliable and versatile, is expensive, with farmers in Sitapur paying on average 12,782 r/ha/season to irrigate their wheat crop. Jalaun however is one of the highest irrigators using canal water in Uttar Pradesh, with the majority of farmers interviewed (33/50) making use of the resource, often in conjunction with groundwater. This provides a cheap, and sometimes free source of irrigation water (Figures 2C and 3). In addition, farmers in Sitapur produce smaller yields than farmers in Jalaun, almost 2 t/ha less (Figure 2D). As can be seen in Figure 2B, and in Figure 4, farmers in Sitapur apply 1,017 m³ of irrigation water with those in Jalaun using only 396 m³ to produce a tonne of wheat. When comparing tubewell users only in both districts further differences emerge. In terms of production efficiency farmers in Sitapur require on average 1,017 m³ of irrigation water per tonne of wheat produced, with their counterparts in Jalaun applying 800 m³ less (Figure 5B). When only tubewell users are taken into account, the price paid per m³ of irrigation water was found to be very different. Farmers in Sitapur pay on average 3.58 r/m³ whereas farmers in Jalaun pay significantly more; on average 8.71 r/m³ (Figure 5D). The fact that farmers apply less irrigation water in Jalaun however (Figure 5A), is reflected in the overall cost of irrigation by both groups (Figure 5C). Farmers in Sitapur pay on average 1,167 r/ha more to irrigate their wheat crops despite the fact that the cost per cubic meter of water is less.

In Jalaun many of the interview participants had access to both tubewells, and the cheaper but less reliable, Irrigation Department supplied canal water. Conjunctive use of surface and groundwater is often promoted as a realistic option to solving groundwater overdraft caused by irrigation ((Harou and Lund, 2008), (Shah et al., 2008)) and developing an understanding of farmer behaviour in this type of environment is important when formulating solutions. To investigate irrigation behaviour between farmers who have a choice in their water source (canal and tubewell) and those who don't (tubewell only), a comparison of the data collected within the district of Jalaun was undertaken, the results of which can be seen in Figure 6. In terms of the volume of irrigation water applied, there was a statistically significant difference between both groups (Figure 6A), with farmers who have canal access, applying over 1,722 m^3 of water more than those who rely on tubewells only. While more water is used by farmers who have access to canals to produce one tonne of wheat (Figure 6B), the difference between the two groups was not found to be statistically significant. The cost of irrigation water however, per m^3, was found to be significantly different between both users (Figure 6D); canal users pay on average 2.09 r/m^3 whereas farmers who use tubewells pay on average 8.71 r/m^3. As can be seen in Figure 6C, in terms of the overall price paid for irrigation by both groups, farmers who have access to canal water are applying more, and also paying 7,805 rupees/ha/season less to irrigate their wheat.

4.2 Qualitative results

The most commonly reported theme during the interviews was that of poor water availability. While no exact measurements were taken by respondents, a significant proportion in both districts reported that they had noticed water levels were dropping. The perception, particularly among groundwater users, was that this was predominantly as a result overuse by other farmers and poor rainfall:

Farmer 1, Dafrapur, Sitapur. Translator: "Maybe because of many people extracting the water".

In some cases farmers reported that while they usually got water eventually, it was often too late to meet their crop water needs:

Farmer 1, Kishun Kheara, Sitapur. Translator: "always get but not always on time".

This problem becomes more pronounced during the dry season, with farmers forced to rely on deeper tubewells, which are fewer in number, leading to a delay in access. Interestingly, a large proportion of farmers in Sitapur, all of whom depend on groundwater, highlighted that they had no issues with water supply. This was often as a result of having reliable access to a deep well, or owning land in an area with a high water table. While farmers in Sitapur are dependent on groundwater, many in Jalaun have access to both canal and surface water. Canals, while beneficial, particularly

in terms of affordability, were perceived as unreliable, with the irrigation department supplied water often arriving late or early for irrigation. This often forced farmers to turn to the more expensive groundwater where available, to ensure their crops were irrigated. Indeed in Jalaun, the lack of access to a reliable water source was deemed to be the main reason for farmer's not growing rice, despite many saying that their soil was suitable:

Farmer 6, Barha Jalaun. Translator: "So he is telling me that he generally grows wheat, ...and don't grow rice because of lack of water, so soil is good for rice, but because of lack of water, they generally don't grow".

According to farmers in both districts, the lack of a dependable electricity supply was perceived as a significant barrier to accessing a sustainable source of water for irrigation. Electric submersible pumps allow for deeper water abstraction and are generally considered to be a cheaper option for farmers than the common diesel pump. Indeed the introduction or improving of electricity in an area was seen by farmers as an obvious solution to water issues in both districts, along with deeper tubewells. The fact that this could lead to further drops in water levels was not mentioned by participants, highlighting the often myopic nature of farmers. Interviewees also singled out the Government for criticism, blaming them for poor infrastructure such as badly maintained wells, the poor electricity supply and corruption:

Farmer 2, Gulriha Sitapur. Translator: "He is saying Government is not doing what they want here",

Farmer 1, Mania Sitapur; Interviewer: "And what do you think are the biggest problems you face at the moment?" Translator: "Lack of fertilizer, lack of water lack of electricity everything, what they say first is everything! Major thing is [Government] corruption".

In Jalaun however, a number of farmers highlighted the benefits of some Government policies, particularly that of free, or cheap canal water. While welcome, farmers saw this practice as a means of securing votes for local politicians. As the participants were given freedom to elaborate where they saw fit, additional information emerged in a number of interviews. In Sitapur this included a system whereby access to water was shared between farmers who owned their own wells. This was outside the water market, a common method of irrigation water access in both districts, and was more prevalent in parts of Sitapur where farms were fragmented. The system allowed farmers to use tubewells owned by farmers neighbouring more distant pieces their land and in return allowing their own well(s) to be used by others with land adjacent to them. Farmers would move their own pumps around to different wells as needed. A lack of labour was also highlighted as an issue for

farmers. This emerged as an important reason why the use of sprinklers was not more widespread. While most were aware of the potential benefits, particularly in Jalaun, implementation was curtailed by the lack of available labour. Climate, particularly the lack of rainfall emerged as a challenge for farmers; however a number of interviewees in Sitapur spoke of the onset of "westerly's", a drying wind which had a dramatic effect on crop water requirements:

Farmer 3, Lilsi, Sitapur. Translator: "Because of westerly's, the wind can carry more and more moisture from the soil".

Poor neighbour relations was also highlighted as a potential problem in accessing water when needed in both districts, but was more prevalent in Jalaun, particularly in terms of access to canal supply, with farmers further down the canal receiving less water. Interviewees also spoke of the damming of canals by farmers upstream as a problem in receiving water on time:

Farmer 4, Kusmra Bavani Jalaun. Translator: "...there is a conflict between the villages because the water distribution and what happens is that the upstream villagers they dam the canal as we have seen and they stop the water for 2 or 3 days".

The perception among many farmers in both districts was that irrigation was not cheap. However this did not appear to change their attitude to irrigation as a reduction in water could lead to a reduction in crop yield. It appeared that farmers were being as efficient in their water use as they could be given the resources they had.

4.3 Comparison with modelled irrigation requirement results

Crop water requirements can be estimated using a variety of algorithms, for example Hargreaves-Samani (Hargreaves and Samani, 1985) or Penman-Monteith (Allen et al., 2005). These approaches are extremely useful as they provide results without the need for field level measurements. It is however important to compare the modelled outputs to field data where possible as results can vary considerably. Here we compare the reported volume of irrigation water applied by farmers to their wheat crop with values obtained through modelling of requirements using Hargreaves-Samani's (Hargreaves and Samani, 1985) potential evapotranspiration method, and the Terrestrial Hydrology Research Group at Princeton University's global meteorological forcing dataset (Sheffield et al., 2006). The crop coefficients used in the calculation are provided by Chowdhury (2012), which are estimated through field experiments in North India. This data allowed for the modelling of wheat irrigation requirements from 1948 – 2012. The results are then compared with the irrigation values reported by farmers during field work undertaken in 2013. The modelled results and the reported values are presented in Figure 7.

The mean value reported by farmers in Sitapur is 4050 m³/ha of irrigation water applied during the wheat season. This is 368 m³/ha below the modelled 2012 result of 4418 m³/ha. The difference in Jalaun is more significant, with a mean reported value of 2283 m³/ha, 2253 m³/ha less the modelled result of 4536 m³/ha. The median reported value of both districts is also significantly lower than the modelled result, (Jalaun: 1390 m³/ha, Sitapur: 3800 m³/ha) highlighting that the majority of farmers apply less water than would be predicted through modelling, showing the importance of using field collected information to address model uncertainties.

The data reported in this section provides an example of the type of information that can be collected using this methodology. While it reveals a considerable amount of detail on the irrigation behaviour of farmers in the region, it is envisaged that this information can be further utilised, particularly in the set up and driving of hydro-economic and groundwater models of the region.

5 OPPORTUNITIES AND LIMITATIONS OF SEMI-STRUCTURED INTERVIEWS

The lack of reliable quantitative and qualitative information is a major barrier in developing realistic water security options. In data scarce regions of the world, information is typically downscaled from larger regional datasets; however this ignores the often significant spatial variability that exists on a finer scale. The use of qualitative, as well as quantitative information is essential in identifying the drivers behind water use practices, however the collection of this information is often expensive and time consuming. Semi-structured interviews provide a means of developing information rich datasets in a time and resource efficient manner. Direct contact with water users and the opportunity to allow them to expand on the issues of most importance to them provides a unique opportunity to develop an understanding of the human water interface in a given location. Despite the usefulness of semi-structured interviews, we identify some limitations in both the data collected and the approach used. The information collected, while useful for informing large scale models, is most applicable to the scale at which it was collected, which ideally should coincide with a scale in which decisions on policy can be made and implemented; in this case district level. The type of data collected, both quantitative and qualitative is useful for driving models, through numerical inputs and in setting rules; for example who has access to which water source and when. As can be seen in section 4.3, the differences between modelled outputs and collected field data can be significant. Incorporating field level information where possible is an important consideration for modellers in order to highlight bias and uncertainty. This also applies to water users and water managers, the approach allows for more realistic conclusions to be drawn from model outputs. In the case studies, interviews took place from September to November. This snapshot of the farming year in Uttar Pradesh is during a time of peak water availability, as it is following the monsoon season. It is possible that this influenced farmer responses. In addition, out of 105 farmers approached, only 5 declined to be interviewed. While this high participatory rate made field work more straightforward, it highlights a potential

propensity for interviewees to please the interviewers or provide statements indicative of social desirability response bias (Collins et al., 2005) which may be reflected in the collected information. In the case study reported above, interviews required the use of translators. Shortfalls associated with using a translator(s) are described in Kapborga and Berterö (2002), however to limit the potential for discrepancy, training should be provided prior to fieldwork. It is also important to remember that in their environment the interviewee is the expert and should be treated as such. This also helps break down some of the barriers which may exist when a researcher and participant are from different cultures. It is important to take these factors into consideration at all stages of the research including subsequent analyses. While the case study sample size (n=50 per district) is small relative to the population [Sitapur = 623,000 farms, Jalaun = 253,000 farms (Uttar Pradesh State Planning Institute, 2012), we are confident that it presents a good representation of farming practices across the district as a whole. Verification of the objective accuracy of self-reported data is also an important consideration. Reported information can be triangulated with, if available, socio-economic data, outputs from other models, or ideally, field level monitoring of water levels, abstraction rates and surface water availability. While checking the data through objective measures is a necessary step in data collection, it is outside the scope of this paper. To address these shortcomings, further field work should be undertaken, focusing on different regions of Uttar Pradesh during more water scarce times of the year, and importantly gaining objective measures of the data reported herein, i.e. via direct observation and metering of the phenomena.

6 CONCLUSIONS:

Our current limited understanding of the human - water interface is a major shortfall in developing options for future water security. One of the major barriers in developing this understanding is a lack of suitable qualitative and quantitative data. In this paper we present a methodology to facilitate the collection of information for hydrological and engineering purposes in data scarce regions through semi-structured interviews. We use this methodology to investigate farmer irrigation practices in the Ganges basin of North India, collecting information from 100 farmers across two districts. Information was collected on topics such as irrigation water volumes, the cost of irrigation, water source and the drivers behind these practices. Statistical analysis of the data, along with some data visualisation is presented. Aspects such as a significant variability in water use practices, as well as insights to farmer behaviours, and their environment are highlighted. The semi-structured interview provides a useful platform for the collection of qualitative and quantitative information simultaneously. This has clear benefits, including directly linking behaviours, and their drivers, to reported numerical values. Semi-structured interviews facilitate the collection of detailed information quickly, easily and relatively cheaply while highlighting themes which may not have been obvious beforehand, as well as pointing out aspects of the study which may no longer be relevant. The data collected also lends

itself to more detailed hydrological and hydro-economic modelling, as well as providing more realistic representations of user behaviour, an essential component in model development. While some limitations do exist we are confident that this approach can be employed by natural scientists as an effective and efficient method of collecting both qualitative and quantitative hydrological information for the assessment of drivers, behaviours and their outcomes in a data scarce region.

Acknowledgements. The authors would like to acknowledge the support of the NERC Changing Water Cycle (South Asia) project; Hydrometeorological feedbacks and changes in water storage and fluxes in Northern India (grant number NE/I022558/1).

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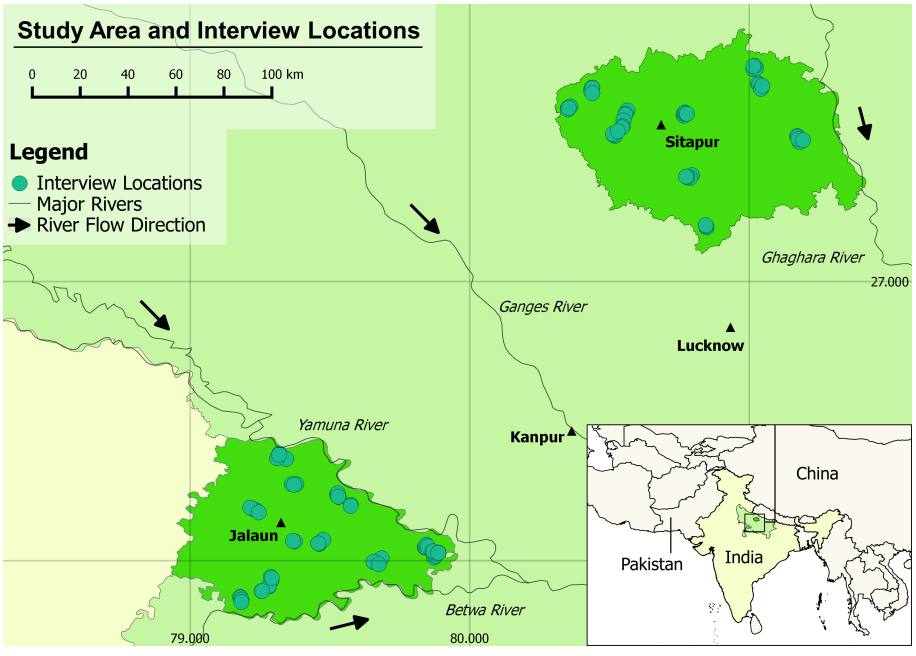

Figure 1: Map of the study region including the locations of the field interviews carried out

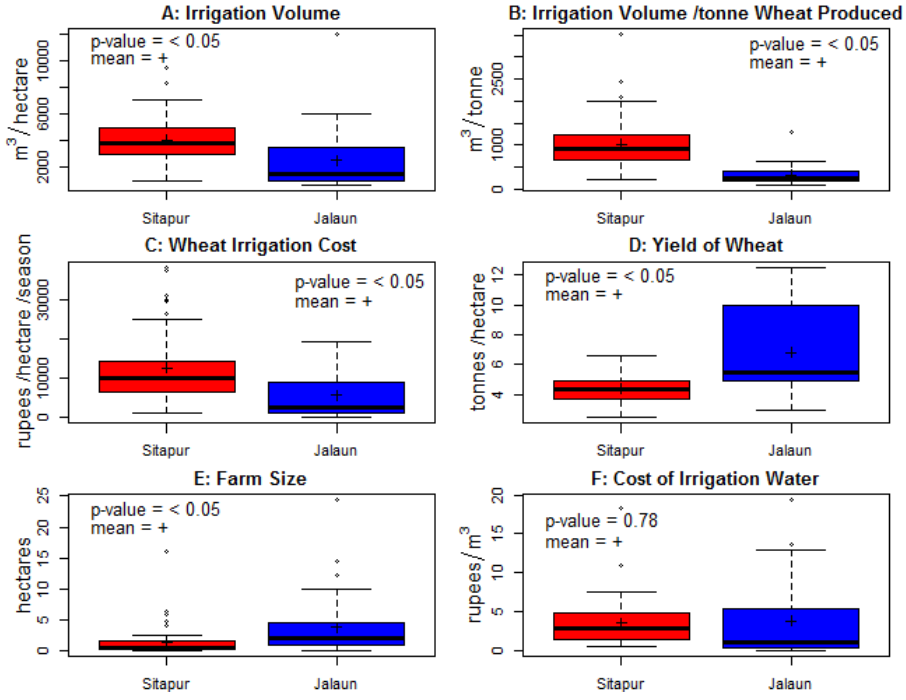

Figure 2: Differences in irrigation practices between the districts of Sitapur and Jalaun, Uttar Pradesh, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range (IQR). The P values give the chance of equal mean obtained from Student's t-test

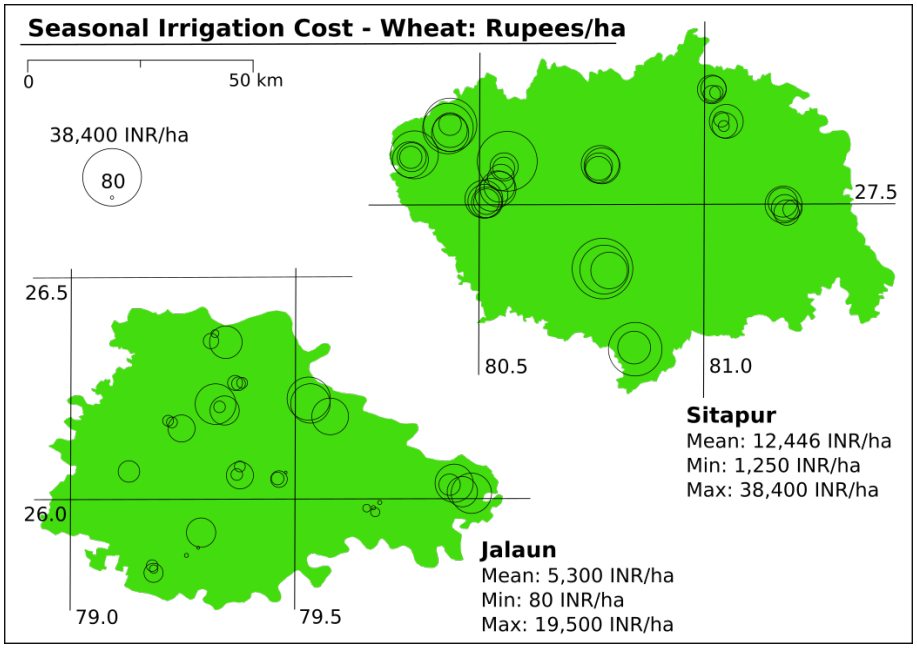

Figure 3: Spatial variations in the annual price paid for the irrigation of wheat by farmers in Jalaun and Sitapur, Uttar Pradesh, North India

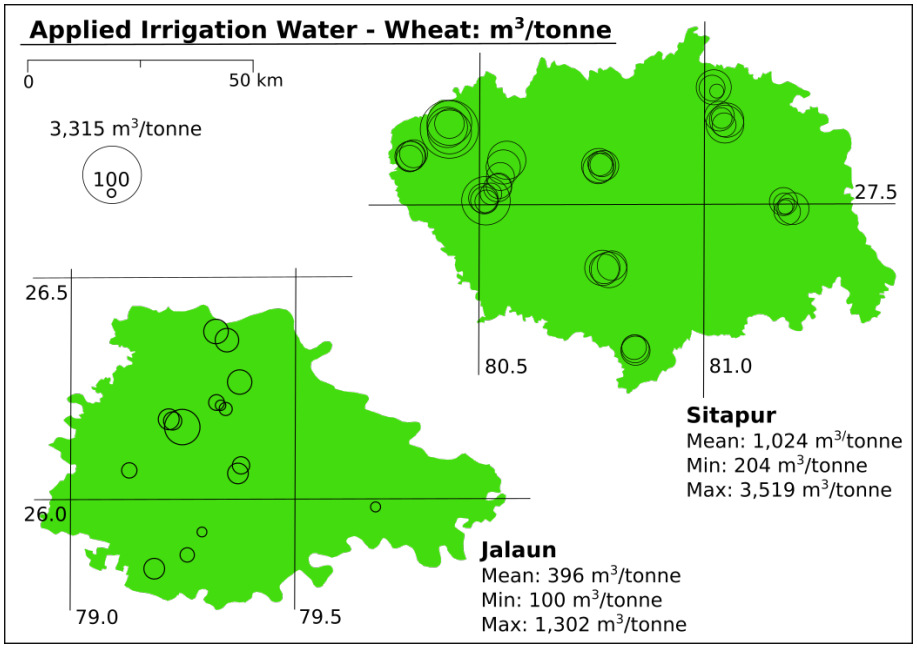

Figure 4: Spatial variations in the volume of water applied per tonne of wheat produced in Jalaun and Sitapur, Uttar Pradesh, North India

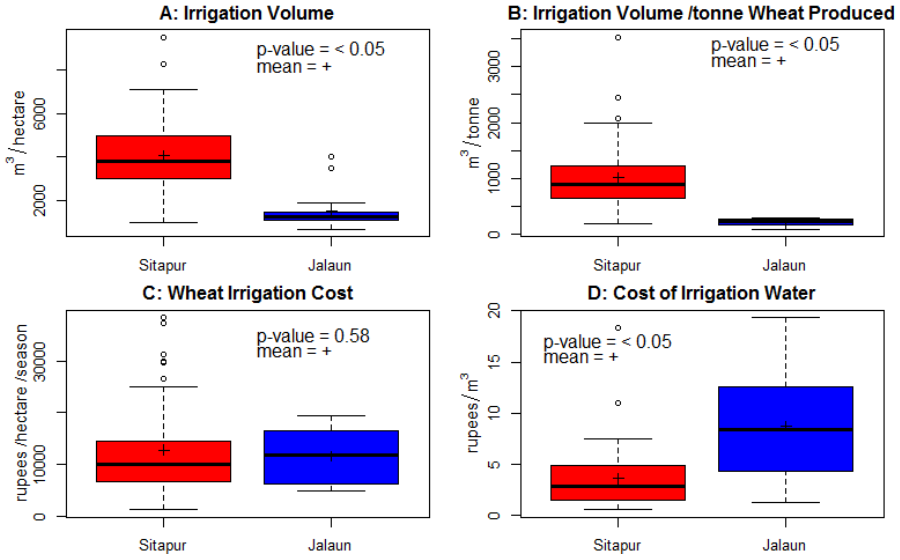

Figure 5: Differences in irrigation practices between tubewell only users in the districts of Sitapur and Jalaun, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range (IQR). The P values give the chance of equal mean obtained from Student's t-test

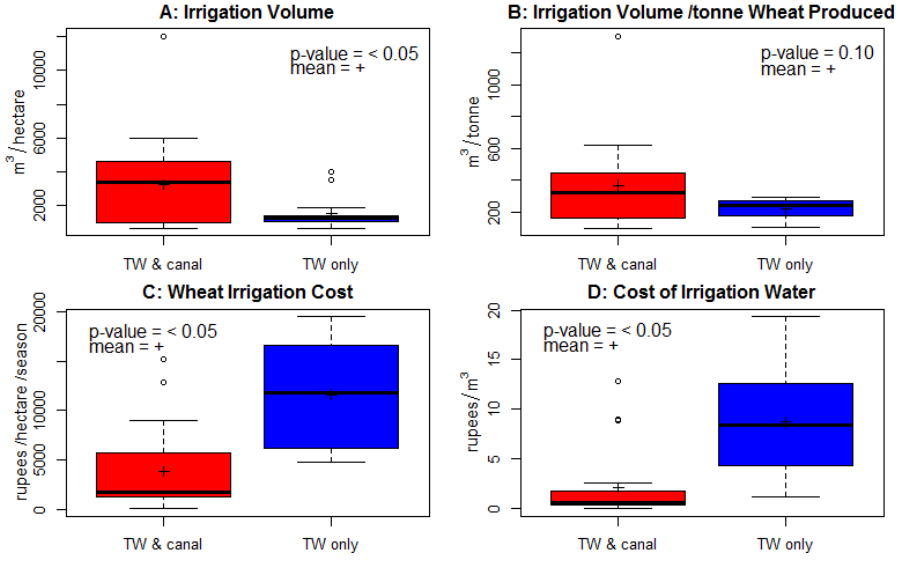

Figure 6: Differences in irrigation practices between tubewell/canal users and canal only users in the district of Jalaun, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range (IQR). The P values give the chance of equal mean obtained from Student's t-test

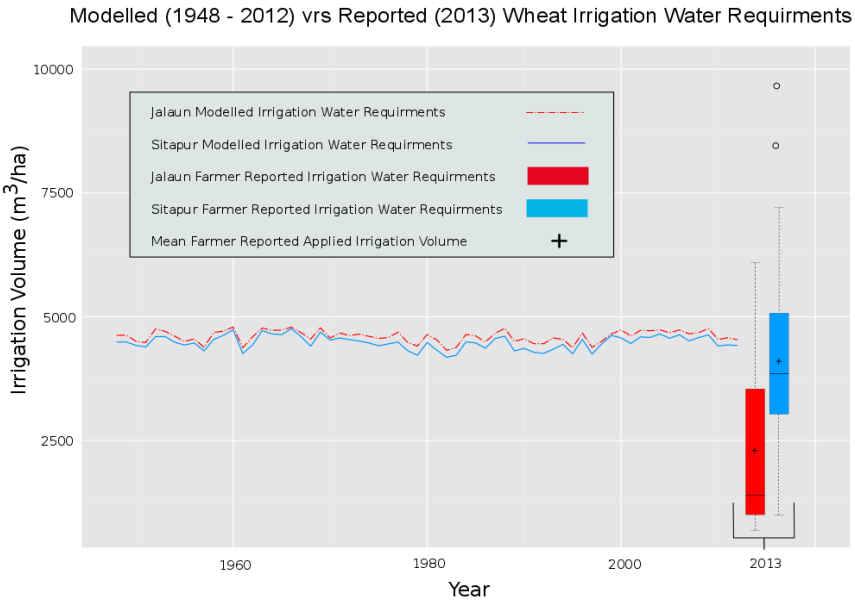

Figure 7: Differences between wheat irrigation volumes as reported by farmers (boxplots) and modelled irrigation water requirments (time series)