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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 to identify relevant issues previously unknown to the researcher. 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 farmers' insights. We present an application of the methodology 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. 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

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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). Water resource management can broadly be categorised into water demand and water supply decisions, which can further be split into irrigative and non irrigative demands (Nazemi and Wheater, 2015a). 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; 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. While such approaches are useful as an overview of large scale issues, they are inadequate for developing realistic solutions at any meaningful implementable level. 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

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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 the methods employed are rarely used in the fields of earth and engineering sciences. For the purposes of data collection for hydrological studies little guidance exists. In a time and resource constrained setting the use of semi-structured interviews provides an efficient and effective method of data collection. This is particularly true of data scarce regions. 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. The use of semi-structured interviews is common in fields which have a strong social science component as the method quickly produces rich and detailed data sets offering an accurate assessment of the impacts of events on an individual (Fallon, 2008). Importantly it can also shed light on the drivers of these events and the motivations behind participant decisions, providing a valuable contribution to earth systems modelling. The semi-structured interview allows information to be collected efficiently and cheaply, in an unobtrusive and open manner.

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In this study we use grounded theory analyses developed by Glaser and Strauss (1967). This inductive process allows the researcher to be guided by the analyses of data, developing a substantive theory through emersion in the collected information (Ellis and Chen, 2013). We propose a methodology for the collection of qualitative and quantitative hydrological data through semi-structured interviews. We apply 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 Sect. 3.

2 Methodology

2.1 Study preparation and interview design

The collection of qualitative and quantitative data in the field requires an understanding of the research subject, in conjunction with the social nuances which exist in a study area. This knowledge is essential when designing the topic guide, around which the semi-structured interview is based (Ellis and Chen, 2013). The pre-fieldwork literature review and planning, which should also take practicalities such as logistics and cost into account, help define the main study area and the target interview participants. 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, be related to their own experiences, be ethically and culturally sensitive and ensure that they assist, rather than impede, the flow of the interview. 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).

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A significant advantage of semi-structured interviews is the opportunity for previously unknown information to emerge. This can occur when the interviewer allows the interviewee sufficient opportunity to speak freely, which can result in the acquisition of novel information, making use of the fact that the interviewees are "experts by experience". This approach allows both quantitative and qualitative data collection and has been demonstrated to yield considerable benefits in terms of quality and cost whilst ensuring a useful representation of parameters. Semi-structured interviews are traditionally comprised of open-ended questions. The collection of quantitative data within a semi-structured interview however is better obtained through direct questions. 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.

2.2 Sampling

Sampling allows us to select cases from a wider population, too big to be studied completely, enabling us to generalise the final research conclusions to the entire population, not just to the individual participants of a study (Flick, 2014). Sampling comprises an integral part of study design. In order to obtain representative data while making best use of available resources; a combination of sampling techniques can be employed. 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 may be necessary to set participant inclusion and exclusion criteria as it is likely that potential interviewees who fall outside the research area inter-

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ests will be approached. Inclusion and exclusion criteria help promote the best use of available resources.

2.3 Conducting the interview

Introducing the study to potential interviewees forms an integral part of the program. 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 conducting a semi-structured interview 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.

In our case study, 100 participants were interviewed during the course of the field work. All interviews were carried out by the same interviewer. Apart from the rephrasing of a number of the questions to better target a particular aspect, or in order to make the question more understandable to the interviewee, the same topic guide was used throughout. As the interviewer did not speak the local language, in this case Hindi, it was necessary to employ translators to facilitate the interviews. Pre-project training should be provided before hand to ensure best practice is followed at all times. Interviews were often 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.

During the interview it is important that all the information is recorded. While there are many ways of doing this, a voice recorder provides a reliable and unobtrusive way

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of recording all the information provided. Again, consent should be sought from the interview participant prior to the recording of any conversation. It is also important that field notes are kept. GPS readings of where the interview took place and any other pertinent locations, for example wells or canal access points should also be taken, along with photos and samples where applicable. The storage of data can also fall under the umbrella of ethics as the research project may involve the collection of sensitive information. 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 were 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, not just what is of interest to the researcher. The use of qualitative data analysis software, for example RQDA Huang (2014) provides a useful platform for processing large amounts of qualitative data.

The first step in data analyses is the setting out of categories based on the collected material. Categories may include; water use, irrigation methodology, irrigation costs, crop information and participant livelihood. A coding guide is then produced whereby all information within each interview is highlighted based on the categories. This is straightforward to achieve using appropriate software which also allows information, both qualitative and quantitative, on each theme to be recalled easily. Once the data has been coded, overviews on the distributions of the variables within the data base can be produced. A significant portion of the data collected should also be quantitative and suitable for some statistical analyses and modelling purposes.

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3 Case study

3.1 Study region: the Ganges Basin, North India

The "Green Revolution" has led to enormous gains in agricultural productivity in India. This has involved the use of more reliable seeds, and an embracing of improved irrigation technology (Singh, 2000). The Green Revolution has allowed India to become food self-sufficient and in doing so has raised Asian per capita food production by 27 % (Jewitt and Baker, 2007). While it has undoubtedly improved life for the rural poor, safeguarded livelihoods and kept food prices in check, the Indian green revolution has also received much criticism for its environmental and socio-economic impacts including a reduction in available water resources on its way to becoming one of the most intensely irrigated areas of the world. Analysis of GRACE satellite data show a dramatic decrease in groundwater resources across North India (Rodell et al., 2009; Tiwari et al., 2009). Satellite data provides a useful method for assessment of changes in water resources, particularly in a data scarce region. However to correctly investigate water security this needs to be coupled with field studies and an understanding of the often highly localised spatial variations in water abstraction.

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). According to Singh et al. (2011), rice is the single most dominant crop in the state during Kharif (the monsoon season from June to October) and wheat during Rabbi (November to April). 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. While the large scale impacts these practices have had 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

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

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 their motivations. Based on irrigation water source information contained within the statistical abstract of Uttar Pradesh (Uttar Pradesh State Planning Institute, 2012) two districts, Jalaun and Sitapur were chosen for investigation. A map of the study area, along with the interview locations is presented in Fig. 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 4565 km^2. 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 ha 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 146 307 ha. 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).

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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). District wise 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 points towards 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.

3.1.3 Interview design

A list of villages within each district was obtained from the State Census (Government of India, 2011) and fifteen were randomly picked from each. A total of 100 farmers were interviewed, 50 in each district. As the focus of the study was to investigate the variation in irrigation behaviour, data was collected under the following themes:

1. farm information (farm size, number of farm sections, soil type);
2. crop information (crop type, crop calendar, yield, price received, crop constraints);
3. irrigation information (water source, number of irrigation events, irrigation volume, irrigation cost, irrigation method, influences on irrigation, presence of water market, power source);
4. aquifer and well information (depth of well, depth to water, pump type, water level fluctuations, cost, constraints, pump information);

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5. canal information (reliability of supply, method of water transfer, number of times used, cost, constraints).

All interviews were conducted using a translator and all information was recorded using a voice recorder.

3.1.4 Data processing and storage

Once data collection was completed, all interviews were transcribed verbatim and uploaded to the qualitative data analysis package, RQDA (Huang, 2014). A number of themes emerged as being important in terms of irrigation behaviour and water use. These form the basis for all following analyses. They include the volume of irrigation water applied, variability in efficiency and productivity, irrigation cost and the variability in yield. Using these themes as the focus, relevant data was coded within each of the geo-referenced interviews. A significant portion of the data collected was quantitative, and allowed for statistical analyses of many of the variables. 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.

3.1.5 Data analyses

t tests were carried out to assess the variance in irrigation practices between and within the two districts. These included the volume of water applied ($m^3\,ha^{-1}$), the volume of water required to produce 1 tonne of wheat ($m^3\,t^{-1}$), the cost of wheat irrigation during the growing season ($INR\,ha^{-1}$), the crop yield in tonnes per hectare ($t\,ha^{-1}$), the farm area (ha) and the cost of irrigation water per cubic meter ($INR\,m^{-3}$). The cost of water in m^3 was calculated by taking into account the cost of irrigation and the volume of water applied per hectare. The results of the analyses can be found in Figs. 2–6, with a description of results below.

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3.2 Discussion and results

The results presented in Fig. 2 and in the maps in Figs. 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 (Fig. 2a); with farmers in Sitapur applying on average 1555 $m^3 ha^{-1}$ more than farmers in Jalaun.

This is also reflected in the overall cost of irrigation with farmers in Sitapur paying on average over INR 7000 ha^{-1} $season^{-1}$ more to irrigate their wheat crop than their counterparts in Jalaun (Fig. 2b). This is despite the basic cost of water per cubic meter being largely the same; INR 3.58 m^{-3} in Sitapur and INR 3.84 m^{-3} in Jalaun (Fig. 2f).

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 INR 12 782 ha^{-1} $season^{-1}$ 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 (32/50) making use of the resource, often in conjunction with groundwater. This provides a cheaper source of irrigation water (Figs. 2c and 3); normally in the region of INR 90 ha^{-1} $season^{-1}$ for wheat. In addition, farmers in Sitapur produce smaller yields than farmers in Jalaun, almost 2 t ha^{-1} less (Fig. 2d). As can be seen in Fig. 2b, and in Fig. 4, farmers in Sitapur apply 1017 m^3 or irrigation water with those in Jalaun using only 396 m^3 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 1017 m^3 of irrigation water per tonne of wheat produced, with their counterparts in Jalaun applying 800 m^3 less (Fig. 5b). Unlike when doing a direct comparison of all farmers surveyed in both districts, when only tubewell users are taken into account, the price paid per m^3 of irrigation water was found to be very different. Farmers in Sitapur pay on average INR 3.58 m^{-3} whereas farmers in Jalaun pay significantly more; on average INR 8.71 m^{-3} (Fig. 5d). The fact that farmers apply less irrigation water in Jalaun however (Fig. 5a) is reflected in the overall cost of irrigation by both groups (Fig. 5c), as farmers in Sitapur also pay on average INR 1167 ha^{-1} 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 Fig. 6.

In terms of the volume of irrigation water applied, there was a statistically significant difference between the scores for both groups (Fig. 6a), with farmers who have canal access, applying over 1722 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 (Fig. 6b), the difference between the two groups was not found to be significant. The cost of irrigation water however, per m^3 was found to be significantly different between both users (Fig. 6d); canal users pay on average INR 2.09 m^{-3} whereas farmers who use tubewells pay on average INR 8.71 m^{-3}. As can be seen in Fig. 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 INR 7805 ha^{-1} $season^{-1}$ less to irrigate their wheat.

The data shown here 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.

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4 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 allowing 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 that location.

Despite the usefulness of semi-structured interviews, we identify some limitations. In many cases interviews require the use of translators. Shortfalls associated with using a translator 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 cultural barriers which may exist between a researcher and participant. Providing a suitable interview environment also forms part of the role of the translator or facilitator. 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 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. 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. To address these shortcomings, further field work will be needed, 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.

5 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-economical modelling, as well as providing more realistic representations of user behaviour, an essential component in model development. While some limitations do exist we are

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confident that this approach can be employed 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.

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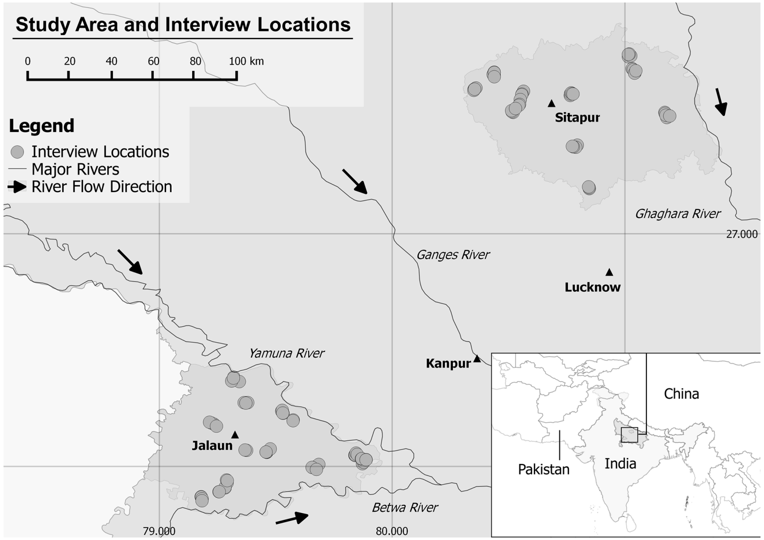

Figure 1. Map of the study region including the locations of the field interviews carried out.

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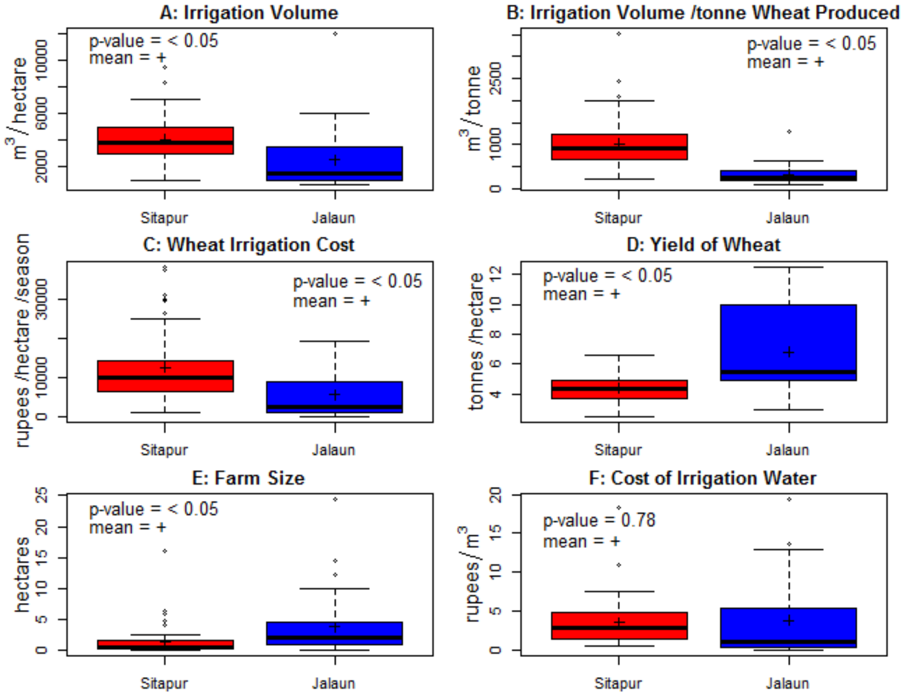

Figure 2. Differences in irrigation practices between the districts of Sitapur and Jalaun, Uttar Pradesh, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range (IQR). The P values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

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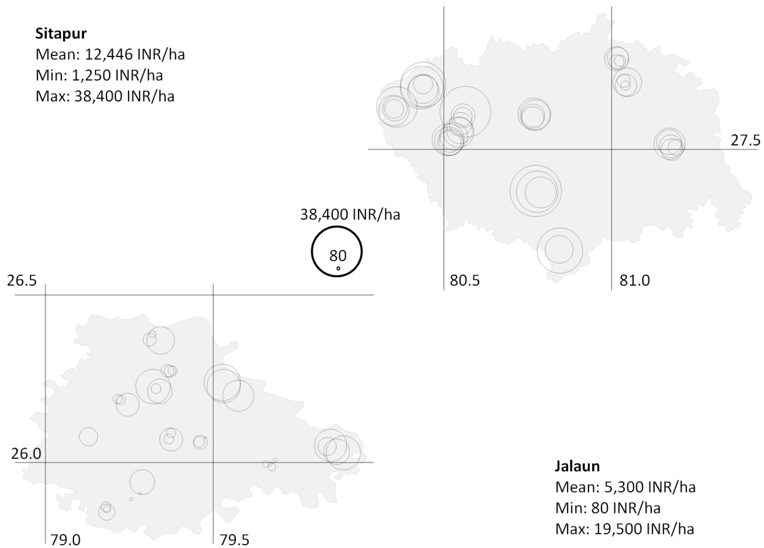

Figure 3. Spatial variations in the annual price paid for the irrigation of wheat by farmers in Jalaun and Sitapur, Uttar Pradesh, North India.

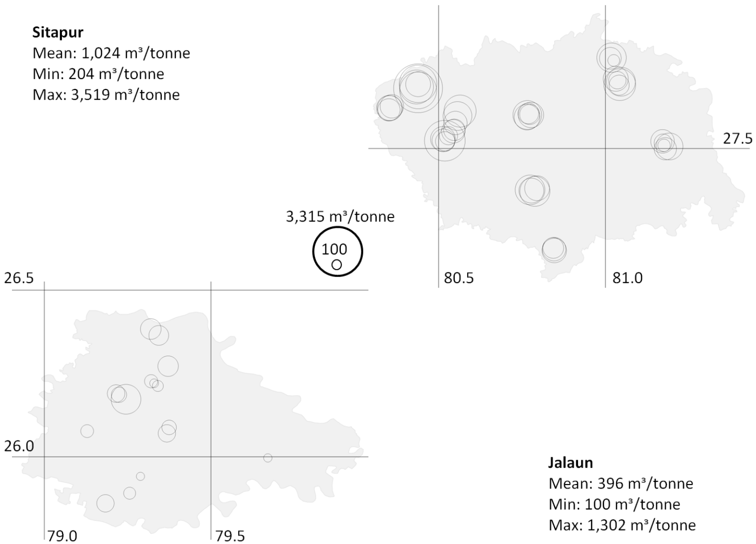

Figure 4. Spatial variations in the volume of water applied per tonne of wheat produced in Jalaun and Sitapur, Uttar Pradesh, North India.

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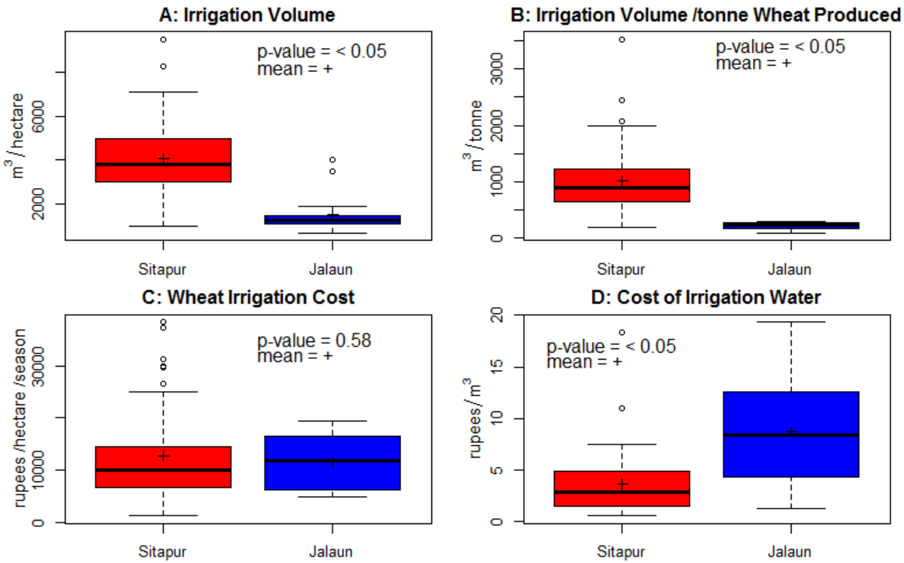

Figure 5. Differences in irrigation practices between tubewell only users in the districts of Sitapur and Jalaun, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range (IQR). The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

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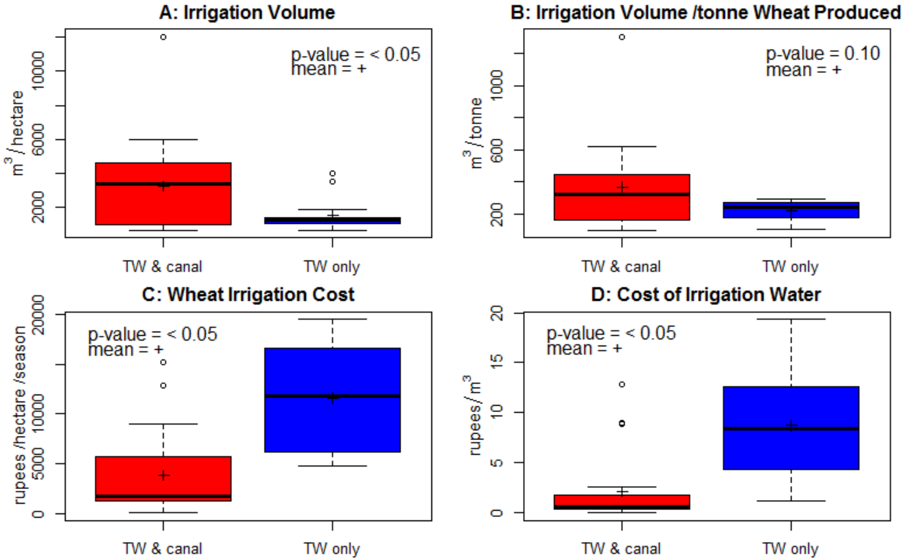

Figure 6. Differences in irrigation practices between tubewell/canal users and canal only users in the district of Jalaun, India. The boxplots represent variability between farmers in each district. The boxes represent the 25 to 75 percentiles; the whiskers represent 1.5 times the interquartile range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

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