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Planning Under Uncertainty: Climate Change, Water Scarcity and Health Issues in Leh Town, Ladakh, India

Daphne Gondhalekar, Sven Nussbaum, Adris Akhtar and Jenny Kebschull

Abstract Access to safe drinking water is already a very serious issue for large urban populations in fast-growing economies such as India. This is further being impacted by climate change, leading to increase in water-related diseases. In regions where water is already scarce, integrated urban planning especially of water resources in conjunction with other sectors such as energy and taking health into consideration is urgently needed. The case study Leh Town, the capital of the Ladakh Region, is located in an ecologically vulnerable semi-arid region of the Himalayas and is undergoing very rapid transformation due to tourism and economic growth. Huge increase in water demand coupled with inadequate water supply and wastewater management are augmenting already serious environmental issues. In 2012–2013, we mapped point sources of water pollution using geographic information systems (GIS), analysed medical data and conducted questionnaire surveys of 200 households and ca. 300 hotels and guesthouses. Our study finds that occurrences of diarrhoea in Leh seem to have increased in the past decade, which may be related to groundwater pollution. Further, over 80 % of the water demand is currently being supplied from groundwater resources without regulation, so that these may be being depleted faster than their rate of recharge. This study discusses using GIS to support urban planning decision-making and advocates a partially decentralized sewage system for water resources conservation in Leh.

D. Gondhalekar (✉) · A. Akhtar
Centre for Urban Ecology and Climate Adaptation (ZSK), Technische Universität München, Arcisstr. 21, 80333 Munich, Germany
e-mail: d.gondhalekar@tum.de
URL: http://www.zsk.tum.de/.

D. Gondhalekar
Center for Development Research (ZEF), University of Bonn, Bonn, Germany

S. Nussbaum · A. Akhtar · J. Kebschull
Center for Remote Sensing of Land Surfaces (ZFL), University of Bonn, Bonn, Germany

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1 Introduction

Rapid urbanization in developing economies such as India is inducing water-related environmental challenges (Marcotullio 2007) as urban water infrastructure planning is often unable to keep up with the pace of development. Resulting lack of access to safe drinking water and adequate sanitation is increasing water-related health risks (Galea and Vlahov 2005), which are further exacerbated by climate change (Vörösmarty et al. 2000). In particular, in regions where water is already scarce, integrated urban planning especially of water resources in conjunction with other sectors such as energy and taking health into consideration is urgently needed.

Health issues do not directly drive urban design, but they did provide the original impetus for the urban planning profession: the discovery in nineteenth-century London that cholera is a waterborne disease, for example, and that it was spreading from one particular contaminated water pump had huge implications for urban planning. Thus, urban design is considered a powerful tool for addressing new public health concerns (Jackson 2003a, b), but new frameworks linking public health and urban planning are needed (Naess 2006) to address contemporary challenges. Studies on the relation between the built environment and health are often confined to certain academic fields, making results difficult to share (Dannenberg et al. 2003). Further, such studies tend to focus on developed country contexts rather than developing countries like India. More cross-disciplinary (Jackson 2003a, b) and international research collaboration (Bork et al. 2009) as well as new approaches (Butsch et al. 2012) are needed to tackle complex water and health issues more effectively.

In India, although one of the earliest examples of public sewerage was found in the ancient Indus Valley (Jha 2010), only 16 % of the urban population today have access to adequate sanitation resulting in large-scale open defecation and thus ground and surface water pollution (WHO and UNICEF 2006). Under similar conditions in nineteenth-century Europe, centralized drinking water supply and sewerage systems proved very effective in curbing water-related diseases and improving public health. However, centralized sewage systems are very water intensive, and expensive to construct and maintain, and energy intensive to operate. Therefore, in regions where water is scarce and where urban areas are facing large-scale development pressures, centralized sewage systems may not be the most appropriate option in terms of water resources conservation. Thus, decentralized sewage systems are increasingly being recognized as a way to help conserve water resources (Lüthi et al. 2011). Although these have various inherent advantages such as the opportunity for nutrient recovery and lower maintenance cost (Tilley et al. 2008), they have rarely been implemented successfully (Sanimap 2009). Instead, the flush toilet

and centralized sewage system, which has been termed "ecologically mindless", remains a preferred option (Narain 2002) and a symbol of "modernity".

In order to illustrate the challenges and opportunities in a development context such as India to implement a decentralized sewage system, we chose a case study where large-scale urban transformation is taking place in a water-scarce region, which could be a lighthouse example for alternative, innovative and more sustainable future development choices in terms of water and health.

2 A Case Study Town in the Desert: Potential Pilot for "Ideal" Sustainable Development

Our case study, Leh Town (hereafter Leh), is located in a remote semi-arid region in the Himalayas at an altitude of 3,500 m above sea level. Adjoining a dense historical town centre, Leh's urban area is spread throughout a green oasis, a valley of agricultural fields and groves of trees watered through a dense network of streams fed by glacial and snow melt water, surrounded by a desert landscape (Fig. 1). This intricate cultural landscape is the product of hundreds of years of very careful management of these limited and also often variable water resources,

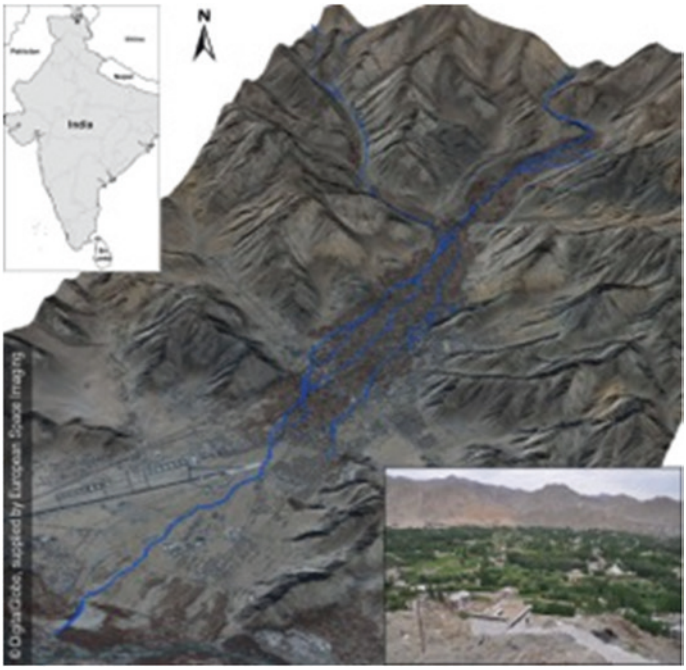

Fig. 1 Geographical location and cultural landscape of Leh

on which many studies have been conducted (Angchok and Singh 2006; Mankelow 2003; Laball 2000; Bhasin 1997; Tiwari and Gupta 2003). With such a water management system enabling food and social security, Leh was a model traditional agricultural irrigation society until only a few decades ago (Norberg-Hodge 1991).

Today, traditional water management and agricultural practices are increasingly making way to changing lifestyles and alternative sources of income especially due to the rapidly growing tourism industry. Leh, the capital and cultural centre of the Ladakh Region of Jammu and Kashmir State, is considered one of the fastest growing small towns in India (Rieger-Jandl 2005: 124). Ladakh is a semi-autonomous region of India governed by the Ladakh Autonomous Hill Development Council (LAHDC). Leh has a population of 30,870 (Census of India 2011). In addition, more than 40,000 army personnel live in Leh (Skeldon 1985) and several tens of thousands of migrant workers come to Leh every year.

Located in a remote region of India close to the borders of China and Pakistan, Leh has only been open for tourism since 1974. Since then, the number of tourists visiting Leh has risen exponentially, especially in the last decade: in 2012, there were 179,000 tourists (Fig. 2), several times more persons than the local population. The vast majority of these tourists visit Leh in summer between April and October because the winters are too harsh for most. In order to accommodate these tourists, there has been a huge increase in hotels and guesthouses in Leh. Tourist accommodations are increasingly building en suite bathrooms with flush toilets and showers to enhance their attractiveness and thus income from tourism. Leh does not have a sewage system, and hotels and guesthouses dispose of wastewater mainly through septic tanks and soak pits that are not being properly managed according to our study. Therefore, we posit that the huge increase in tourist accommodations and the ensuing increase in wastewater may pose a human health risk as the aquifer underlying Leh, which is fed by glacial and snow melt water, is used for drinking water and may be polluted due to seepage.

In fact, Leh is almost wholly dependent on glacial and snow melt water. Rain in the region is negligible and plays an insignificant role in the local water cycle due to the high rate of evapotranspiration, a result of dry air and intensive solar radiation. Occasionally, cloudbursts occur in Ladakh which cause flash floods because the landscape is so dry and without much vegetation, so that it cannot retain any

Fig. 2 Year-wise number of visitors to Leh (*Source* Leh Tourist Board)

water. Leh was hit by such a flash flood in 2010, which killed around 200 people and caused large-scale destruction. Surface water from glacial run-off also seems to be decreasing (Eichert 2009: 53) possibly due to climate change.

In our study, we set out to understand how urbanization processes have been affecting human and environmental health in Leh especially in terms of water resources management. We focused mainly on the last decade, when the largest increase in tourists took place. Our aim is to find out whether there are opportunities in Leh for integrating various sectors related to urban planning, like drinking water supply, wastewater and solid waste management, energy, and tourism infrastructure, in order to address human and environmental health issues in a comprehensive manner. We ask the question, could traditional wastewater management practices potentially hold a key to addressing water-related sustainability issues in Leh?

3 Rapid Urbanization and Human Health: Diarrhoea is a Common and Serious Health Risk

One of the leading water-related diseases, diarrhoea, is already a major public health concern in developing countries such as India, to which children are especially vulnerable: diarrhoea accounts for 16 % of deaths of children under 5 years of age globally, one-third of which occur in India (White Johansson and Wardlaw 2009: 5–7). Diarrhoea can have a number of causes, but the main transmission route is through drinking water (Howard and Bartram 2003; Sakdapolrak et al. 2011: 88), and nearly all deaths due to diarrhoea worldwide could be prevented through access to safe water, adequate sanitation and good hygiene (White Johansson and Wardlaw 2009: 10–13).

An increase in waterborne diseases such as hepatitis and diarrhoea was already reported in Leh over a decade ago (Bashin 1999). However, so far, no comprehensive study exists on incidences of water-related diseases and their potential causes in Leh. Our study tries to address this gap.

We were able to procure data on acute diarrhoea from the chief medical officer (CMO) for the whole of Leh District, which includes Leh Town and several surrounding villages, from 2001 to 2012. These data are hundreds of handwritten sheets in folders sorted by year, which we photographed at the CMO's office and then digitalized. There is a data gap between 2008 and 2010: apparently cows ate some of the folders during the renovation of the archive where they were being stored a few years ago. In addition, we conducted a socio-economic questionnaire survey of 200 households in Leh selected at random, representing 5 % of all households.

The CMO's data show that a significant portion of the population, namely over 10 %, seems to be affected by acute diarrhoea on a yearly basis. Further, when looking at the monthly occurrences of acute diarrhoea over the past decade, the

dashed trend line is following an upward course that seems to suggest an overall increase with peaks in the summer months (Fig. 3). However, these data also include tourists, who are susceptible to diarrhoea in Leh due to unfamiliar bacteria and altitude sickness. Nonetheless, the data also show that over 10 % of the under-5-year-olds in Leh seem to be affected by acute diarrhoea on a yearly basis. Here, we assume that most small children are locals and not tourists because we observed relatively few tourists in Leh accompanied by small children.

The figures seem high, but we cannot compare them because in a country like Germany, for example, statistical data on a health issue like acute diarrhoea are not collected unless there is an epidemic. Even if data were collected, definitions of what constitutes acute diarrhoea may differ. Often, in developing countries, diarrhoea is not regarded as a health issue: because it is so common, it tends to be regarded as a fact of life. The CMO's data only cover persons who visited government health institutions such as hospitals and clinics in Leh to see a doctor for acute diarrhoea. Hence, we assume that the number of people suffering from diarrhoea in Leh but who do not consult the doctor is actually much higher. In addition to being a serious health risk, incidence of diarrhoea also has economic implications as it can rend people unfit to work or reduce their working capacity.

Unfortunately, we found that it is difficult to gather information on diarrhoea from the local population: culturally, it is a sensitive topic to talk about. Further, measuring water quality to try to establish a causal connection between water pollution and diarrhoea incidences was beyond the scope of our project. Therefore, we decided in our household survey to focus on people's perception of water quality in Leh and its perceived impact on health and potential impact on water consumption practices. Our hypothesis is that regardless of actual water quality, perception of it will influence how people consume it: for example, a rumour about bad water quality of a particular well may stop people from using it without knowing whether and why the water is polluted, and vice versa, the rumour may well be based on experience values made by the local population.

We found that although 98 % of households thought that drinking water quality is safe in Leh, 53 % of households thought drinking water quality today is worse

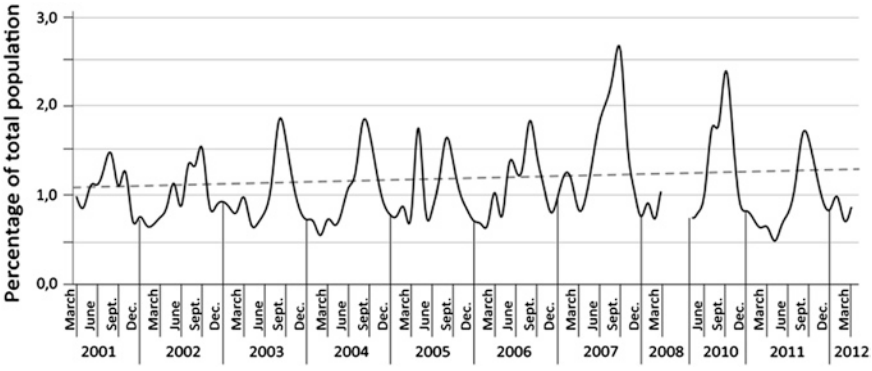

Fig. 3 Incidence of acute diarrhoea in Leh district

than 10 years ago. 34 % of households reported problems with their drinking water in terms of it having a strange smell, taste or colour. Lack of adequate wastewater management and treatment, i.e. septic tanks or soak pits, were thought by 26 % of households to be the main source for groundwater pollution. The local population also perceived increased use of chemical fertilizers over the past decades in agriculture as a water quality threat. 34 % of households thought diarrhoea is related to drinking water pollution. Thus, this study found drinking water pollution to be a serious concern of the local population.

4 Growth of the Tourism Industry: Implications for Food and Social Security

In order to accommodate the huge and increasing numbers of visitors, there has been a dramatic increase in the number of guesthouses and hotels in Leh in the past decades: in the 1980s, there were only 24 guesthouses and hotels in Leh, but by 1990 there were 62, by 2000 there were 117, by 2010 there were 282, and just from 2010 to 2012, the number had increased to ca. 360 guesthouses and hotels in business, with another ca. 60 not yet in business or under construction. Of 21 wards in Leh, 10 have agricultural land, while the others are predominantly desert like. We found that over 90 % of guesthouses and hotels in Leh are located in wards with agricultural land area (Fig. 4).

Only 40 % of Leh's population lives in the agricultural wards although these cover 1,358 ha compared to 535 ha for non-agricultural wards. In the agricultural wards, houses tend to be traditional Ladakhi multi-generation one-family clay-construction houses, many of which have been converted into guesthouses, and in non-agricultural wards, buildings are concrete slab constructions. 36 % of all households originate in Leh, of which 85 % live in agricultural wards, while for other households originally not from Leh, only 31 % do so.

In order to measure land use change in the two wards with the highest rate of urbanization over the past decade, we compared a high-resolution satellite image of 2011 with a Google Earth image of 2003. As Leh is located on a slope, individual fields are clearly visible in satellite imagery because each field is circumscribed by a stone wall which allows farmers to flood and thereby irrigate the individual fields. After digitizing each agricultural field, we compared the two images to see which areas that had formerly been agricultural land had been turned into built-up area.

We found that in these two wards, 14 % of agricultural land had been transformed into built-up land in the past decade. In addition, we found that in the same two wards at least 30 % of the land that was used for agriculture (32 of 97 ha) has fallen barren within only the last decade, between 2003 and 2011 (Fig. 5). Due to the property rights in Leh, fields are rarely divided up. Therefore, we hypothesize that when a household formerly active in agriculture constructs a guesthouse on an agricultural field or converts an existing house into a guesthouse, the income

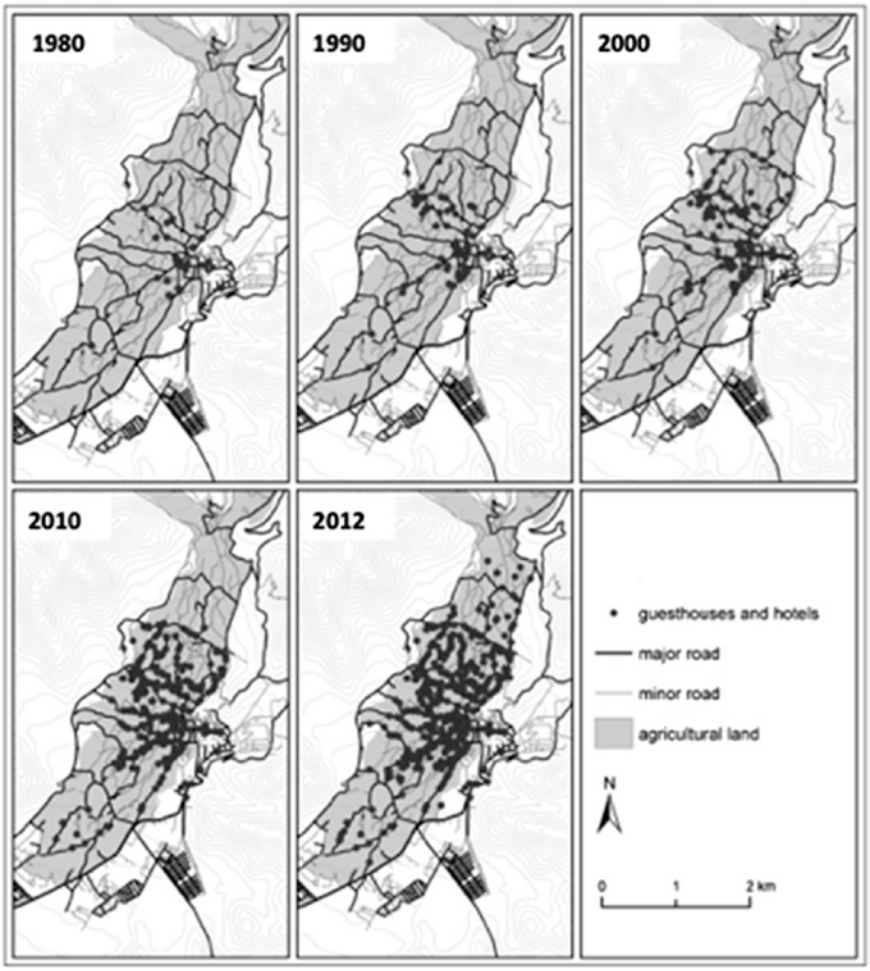

Fig. 4 Increase in hotels and guesthouses since 1974

from the guesthouse may make any income from agriculture redundant. Thus, the agricultural land area, even if only partially covered by the new guesthouse, may be left barren.

The trend of decreasing agricultural activity is also visible in the results of the household questionnaire survey. We found that average income in Leh has doubled in the last decade. Overall, agriculture was a source of income for 28 % of households 10 years ago, but is now only a source of income for 13 % of households. For those households still engaged in agriculture in Leh, the amount of land being farmed on average has decreased from 0.29 ha 10 years ago to 0.12 ha per household, a marked decrease of 59 %.

As recently as 40 years ago, Ladakh was a predominantly agricultural society (Norberg-Hodge 1991) that was to a large extent self-sufficient in terms of food

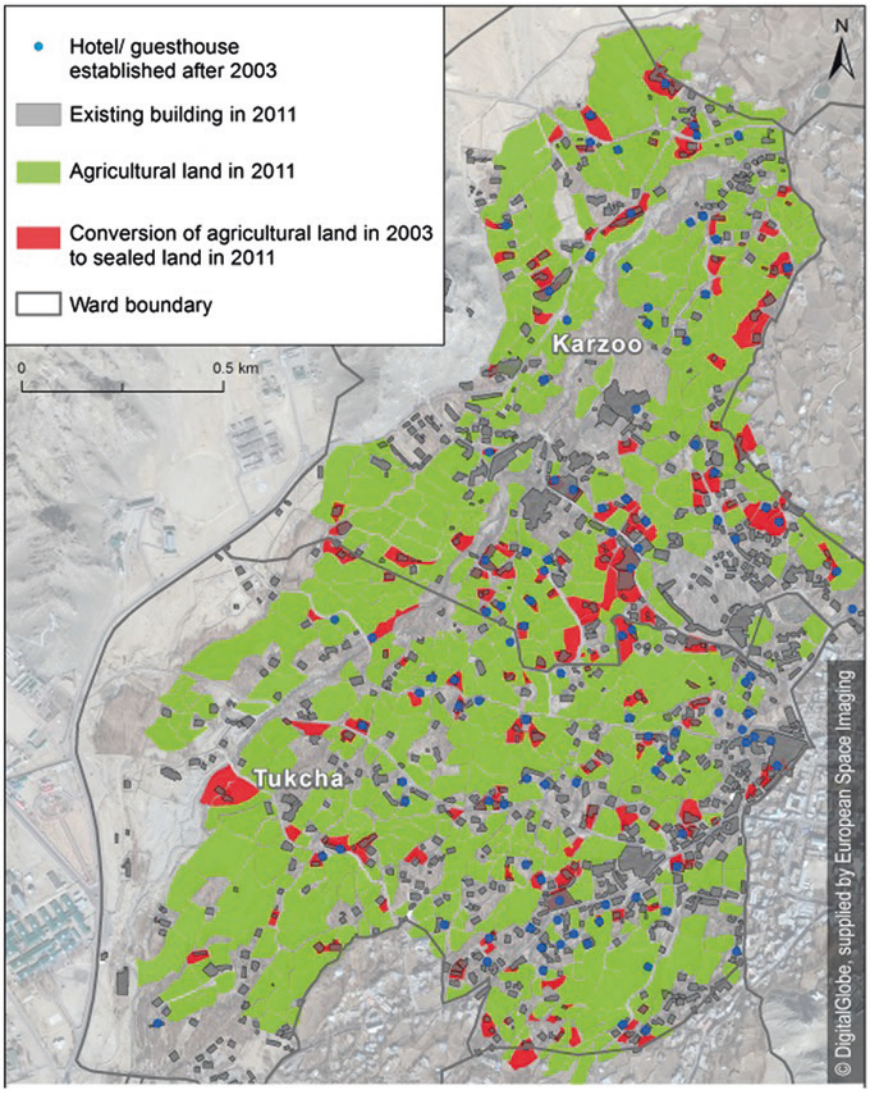

Fig. 5 Barren land in Leh's rapidly urbanizing wards

production. Today, Leh already has a food-grain import dependency ratio of 60 % (Pellicardi 2010: 89). The decrease in agricultural land measured in Leh is a significant amount, which needs to be addressed with a view to food security. Further, decrease in agricultural land also means decrease in irrigated land area, which in turn may be impacting the recharge rate of the groundwater aquifer. To address food security in Leh, LAHDC is planning to turn an expanse of desert area on the orographic left side of the Indus River into irrigated agricultural land. However, this may require huge additional amounts of groundwater extraction or diversion of Indus River waters.

5 Rapidly Rising Water Demand: Are Limited Water Resources Being Overexploited?

When we walk around Leh, ever accompanied by the sound of water that in some fields and marshy areas even bubbles directly from the ground, we tend to forget that Leh is situated in a desert.

The huge increase in tourists in Leh signifies a huge increase in water demand as guesthouses and hotels strive to provide flush toilets and showers as described above. In Leh, freshwater is supplied by a centralized and by a decentralized system. Currently, the public health engineering department (PHE) supplies following daily estimates during summer months (PHE 2013):

a. 1–2 million litres extracted via four tube wells from the Indus River aquifer;
b. 1.3 million litres extracted from various tube and borewells inside Leh;
c. 0.8 million litres channelled from various springs in the upper catchment area of Leh.

Thus, PHE is currently providing 3–4 million litres of water per day and most of it through groundwater extraction via bore and tube wells. The Indus River aquifer is used for PHE tube well extraction, while a deep aquifer underlying Leh, fed by glacial melt water, is used for private and PHE tube and borewell extraction. There is apparently another shallower aquifer underlying Leh. Water from the Indus River aquifer is being lifted about 300 m up to reservoirs distributed in Leh, which is very energy intensive, from where it is distributed by a gravity pipe system with several hundred public and private water taps and water tankers. For those without access to PHE water, public hand pumps are distributed throughout Leh that draw water from the shallower Leh aquifer at a maximum depth of about 10 m. According to our survey, Leh has 46 public hand pumps. 85 % of households use PHE taps, 18 % hand pumps and 8 % borewells as their primary drinking water source.

However, when we surveyed 318 guesthouses and hotels (90 % of total) in Leh, we found that 60 % of all guesthouses and hotels use a private borewell as a decentralized water supply source. One hotel owner interviewed of a hotel with 18 en suite rooms reported extracting up to 8,000 litres per day during the tourist season. Overall, guesthouses and hotels may be extracting up to about one-third the amount daily from the aquifer underlying Leh during the tourist season that PHE extracts daily. According to our interview survey with various local stakeholders, reasons for the increasing use of private borewells are water shortage in the centralized system; that is, PHE only provides water for 2–3 h in the mornings, which is considered insufficient to run a guesthouse or hotel with showers and flush toilets, and concern about PHE water quality and lacking water pressure.

When we look at a map, the high-density areas of groundwater extraction by private borewells in Leh (Fig. 6) predominantly overlap with the highest densities of guesthouses and hotels in direct proximity to the town centre. Outliers are large hotels that are removed from the town centre to profit from a quiet atmosphere. Interestingly, spatially, the location of the pipeline is also close to the highest densities of groundwater extraction, although water supply closer to the pipeline,

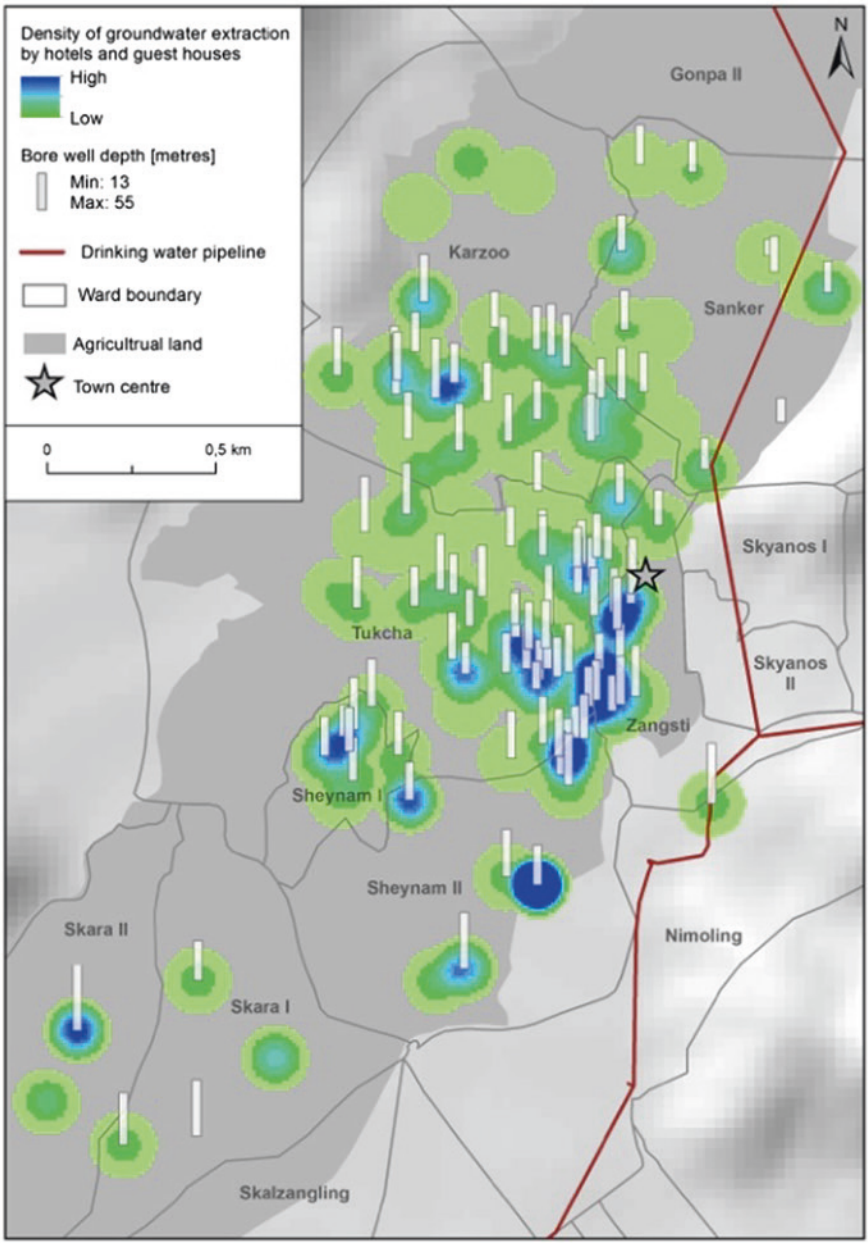

Fig. 6 Centralized and decentralized water supply systems

along which the service reservoirs are located from which water is then distributed via gravity pipe system, maybe better than far from it.

Hence, centralized water supply by PHE cannot match the demand for water in Leh. And even if PHE did provide for the water demand, guesthouse and hotel owners might still prefer to have private borewells to secure water for the tourism industry. However, we found that 99 % of guesthouse and hotel owners are interested in participating in a water-saving sanitation pilot study, which seems to indicate concern on the sustainable use of water resources in Leh.

Groundwater extraction in Leh is not regulated, and the capacities of the Indus River aquifer and the aquifer under Leh are not known. Further, not only the extraction but also pumping the water up hundreds of metres vertically and several kilometres horizontally from the Indus River aquifer to Leh is very energy intensive. Further, the amount of glacial and snow melt water may be decreasing or becoming uncertain due to climate change (Barnett et al. 2005; Bhutiyani et al. 2010; Immerzeel et al. 2010), hence affecting the amount of groundwater available in the aquifer. According to our interview survey, inhabitants think that some springs in Leh seem to have dried up because of high rates of groundwater extraction.

6 Pollution of Limited Freshwater Resources Through Inadequate Wastewater Management

Since about one-third of households, as described above, voiced concern over groundwater pollution due to lack of adequate wastewater treatment, we mapped where water pollution is occurring in terms of soak pits and septic tanks belonging to guesthouses and hotels, as we assume that these are producing much more grey and black wastewater than local households. Grey water is from kitchens and bathrooms, and black water is from toilets. To do this, we used global positioning systems (GPS).

We find that high-density guesthouse and hotel wastewater disposal sites are clustered around the town centre. This is not an obvious product of guesthouse and hotel density, because guesthouses and hotels closer to the town centre could be receiving more tourists, hence be richer and thus more likely to invest in wastewater treatment. Highest densities of wastewater disposal are also found in proximity to the PHE drinking water supply pipeline, so that seepage and thus freshwater pollution may have to be assumed. However, households in agricultural and non-agricultural wards alike think that groundwater is being polluted by lack of adequate wastewater management (Fig. 7).

According to the World Health Organization (WHO 1996), freshwater extraction locations should be a minimum of 30 m away from wastewater discharge locations. To estimate to which degree the quality of the groundwater in Leh is potentially at risk from sewage seepage, we spatially related areas of high wastewater production to areas of freshwater extraction such as borewells and hand

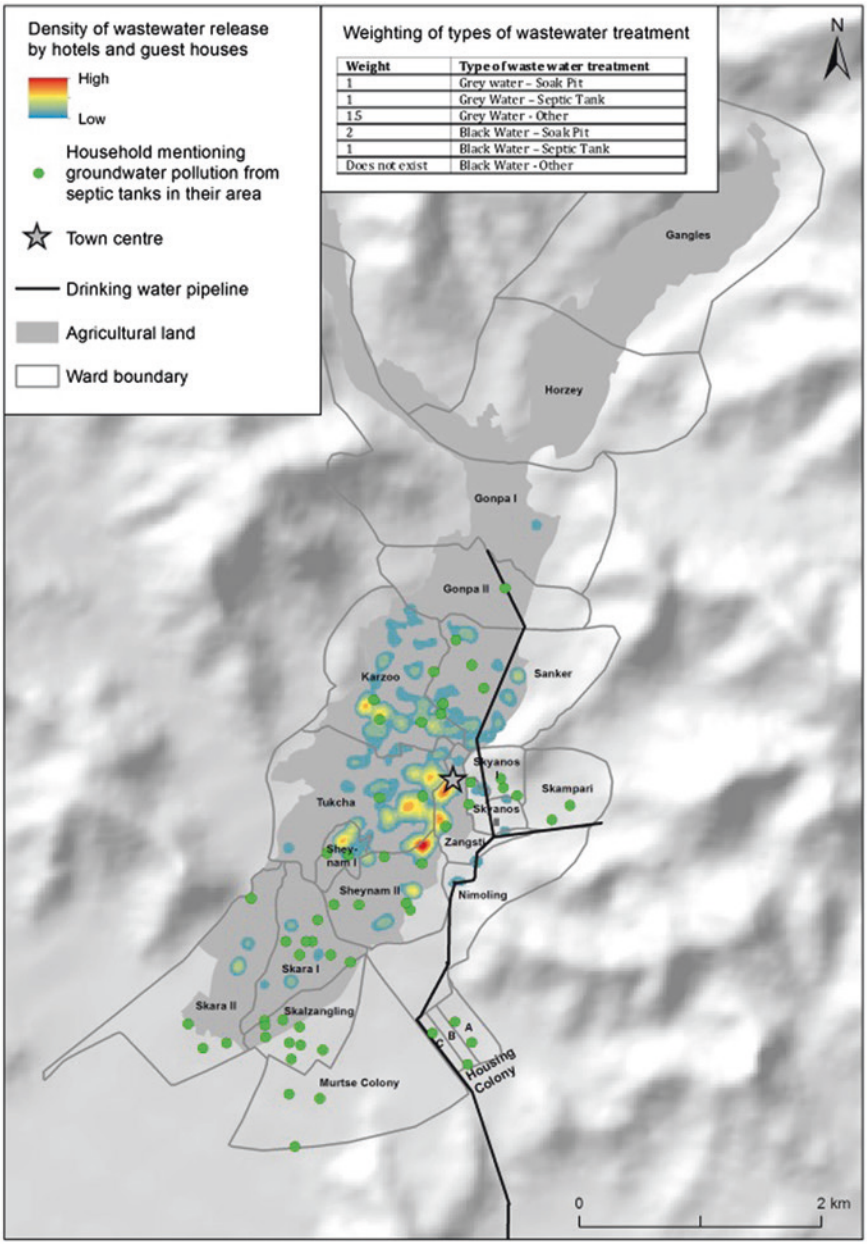

Fig. 7 Wastewater production and perception of groundwater pollution

pumps. We found that 33 % of freshwater extraction points in Leh are too close to areas of wastewater disposal and 4 % are too close to highly polluting wastewater disposal areas. Thus, the water quality of these freshwater extraction points may be at risk. The average bore well depth of guesthouses and hotels in Leh is 33 m, so that water quality of these may generally be at risk. As mentioned earlier, in some areas in Leh, the groundwater aquifer is very shallow and water just bubbles from the ground, and these areas may need special protection.

In addition, pollution of surface waters due to inadequate wastewater and solid waste management is also a significant issue in Leh. In the agricultural wards of Leh, we mapped 270 surface point sources of water pollution. Of all point sources of water pollution, 80 % are grey water inlets, which is of concern because with grey water, chemicals are being released into the water system from detergents used for cleaning and washing purposes. We also mapped 23 black water pollution sites including black water inlets (from toilets), public toilets without septic tanks and foul-smelling empty lots being used for open defecation, and soak pits other than those of hotels and guesthouses, and 18 open garbage dumps. Overall, 62 % of surface point sources of water pollution in the wards with predominantly agricultural land in Leh Town are within 100 m of rivers and streams. According to World Health Organization guidelines, this implies that open waters in Leh are directly being polluted. Overall, the type and distribution of water pollution in Leh indicates that strict environmental planning is needed as currently the quality of limited drinking water resources may be at risk.

7 Traditional Wastewater Management: An Opportunity for Development Innovation

A traditional form of decentralized wastewater management infrastructure, the Ladakhi dry toilet, which is very well adapted to the local conditions, has been in use in Ladakh for hundreds of years and is still used by the majority of the local population. The Ladakhi dry toilet is an elevated slab with a hole in the middle, sometimes as part of a house or as a separate outhouse, where faecal matter falls into a chamber beneath the slab and is covered after each visit by a shovel full of earth—hence “dry” as no water is used. The faecal matter is stored and used as dry agricultural fertilizer on the fields. The Ladakhi dry toilet is still used by 30 % of local households as a source of organic agricultural fertilizer.

Although it seems that richer households are more likely to own a flush toilet, overall, in Leh, 60 % of households do not have a flush toilet. In summer, 67 % of households use dry toilets and 28 % use a combination of traditional Ladakhi dry toilets and flush toilets. In contrast, only 1 % of tourists admit to using a Ladakhi dry toilet in Leh (Akhtar and Gondhalekar 2013: 31). In winter, 91 % of households use a Ladakhi dry toilet as the piping systems of flush toilets tend to freeze.

In order to deal with increasing amounts of wastewater, LAHDC will start this year to implement a centralized sewage system designed for the year 2040

through a private consulting and engineering company. This system is planned to comprise about 75 km of piping to be laid at a depth of 2 m below the surface to avoid freezing in winter. The collected wastewater is to be channelled to a central wastewater treatment plant below Leh on a barren land area, from where treated water is to be discharged into the Indus River (Tetra Tech 2009). However, such a centralized sewage system may require increased water supply just in order to flush long pipes, which will in turn require more energy for extraction. Such energy will need to be supplied, but energy provision is already a challenge in Leh, with the town facing regular power cuts. Further, a centralized sewage system may entail high operation and maintenance costs due to the harsh climate and rugged topography.

Despite these seemingly natural constraints to the implementation of a centralized sewage system, nonetheless, such a system represents an opportunity for the local government to invest in large-scale infrastructure. Further, the centralized sewage system may symbolize the "modernity" that a society facing the burdens of rapid transition and as recently still as traditional as Ladakh wishes to strive for. With its apparent record of success, the centralized sewage system still stands for the "business as usual" option to deal effectively with wastewater in an urban context.

In contrast, however, a decentralized sewage system in the parts of Leh that are less dense than the historic centre and have much agricultural land area may help address wastewater management challenges as well as to conserve groundwater resources by enabling the following:

- Length of overall piping system may be much less and may require less water for flushing
- Nutrient recovery in the form of organic as opposed to chemical fertilizer, enabling lower environmental impact of agriculture and continuation of traditional agricultural practices
- Reuse of treated wastewater in agricultural irrigation locally
- Less environmental pollution of soil and water resources and loss of water due to less seepage due to shorter pipes
- Lower energy consumption due to less water having to be lifted from groundwater resources and pumped uphill and pumping water within the pipe network to overcome topographic differences
- Renewable energy use potential through smaller pumps that can be powered by solar power
- Renewable energy production potential such as biogas from faecal sludge
- Lower costs of construction, operation and maintenance

In addition, wastewater could be treated and channelled back to replenish the aquifer underlying Leh proportionally to water demand and rate of extraction locally. One hotel in Leh has already implemented its own decentralized wastewater treatment plant out of environmental considerations. However, this is so far an exception.

8 Visioning Alternative Future Development in Leh, and Getting the Vision to the Ground

Leh in many ways is an ideal case study: until only a few decades ago a purely agriculturalist society, many inhabitants still practice agriculture for their own food production and also to cook for tourists in the guesthouses. Traditional wastewater management practices of collecting faecal sludge and using it as organic fertilizer on the fields of Leh are still widespread. Leh has been facing large-scale development pressures in a very fragile ecological environment in the very short space of only a few decades. However, the continuation of traditional agricultural and wastewater management practices may hold the key to enabling an alternative form of "modernity" in Leh that may be more suited to its locational characteristics and more appropriate in terms of water resources conservation than a centralized sewage system.

Yet devising such an alternative solution for Leh is a very complex affair that requires new tools as well as new ways of thinking. A geographic information system (GIS) can be used as a spatial decision support system (SDSS), generally described as a computer-based system to assist decision-makers while solving a spatial problem (Sprague and Carlson 1982). This can be a very useful tool to model alternative future development scenarios highlighting the potential water and energy savings and can thus support long-term decision-making on urban planning issues in Leh. For example, our mapping of the private borewells of guesthouses and hotels enabled us to tell where the highest densities for water demand are spatially located and how they relate to available water resources of the PHE pipeline. Or, a suitability site analysis determining the best places for establishment or construction of new guesthouses and hotels could be conducted. This analysis process is a typical example of a so-called multi-criteria approach where different actors with competitive interests and goals need to be considered. However, currently, LAHDC does not use GIS and faces severe constraints in terms of personnel and budget, and seemingly more pressing issues that need to be dealt with on a daily basis in order to supply water to the local population. Hence, for a comprehensive SDSS, models and tools need to be developed which enable political decision-makers to utilize geospatial analysis without too much capacity building.

In our interview survey, various key stakeholders agreed that it is a pressing issue to manage limited water resources in a more comprehensive manner in Leh. Our project is being supported by a local non-governmental organization, the Ladakh Ecological Development Group (LEDeG), and has been approved by LAHDC at a joint inception workshop. In parallel, another research project in collaboration with the Indian non-governmental organization ACWADAM is ongoing to test groundwater quality in Leh, results of which are pending. Therefore, the levels of water pollution are currently not known. So far, also there has been no systematic study to determine the volume of the aquifer underlying Leh, and assessing this is very costly. Therefore, it is currently not known whether

groundwater resources are being overexploited, for example whether the rate of extraction of the aquifer underlying Leh is higher than the rate of recharge. Hence, also in light of projected continuation of guesthouse and hotel construction in Leh, LAHDC needs to plan under uncertainty. However, defining a point in time to act under such uncertainty is extremely difficult. Also, taking a political decision to implement an alternative solution such as a decentralized sewage system is difficult when the facts are not at hand to throw light on its potential benefits.

In this situation, and wanting to address the issue of inadequate wastewater management quickly, LAHDC is prey to companies who want to sell the "business as usual" option, namely a centralized sewage system in Leh. Further, being semi-autonomous, LAHDC is also attracted to a large-scale investment opportunity that such a centralized sewage system is. Despite evident need for wastewater management infrastructure, implementing a large-scale technological option like a centralized sewage system may also seem more feasible to the government than getting embroiled in a potentially time-consuming sociocultural process of trying to implement a decentralized alternative to it. But which role should the government play in order to enable sustainable development choices? It seems that a stronger role by the government is required as the only entity with the resources to implement long-term alternative development options. An SDSS could support LAHDC in its role as a "parent" to sustainable development in Leh.

If funds are short, there may be other ways to procure the finances to implement an alternative decentralized sewage system without an investor being needed. Leh currently does not levy a tourist tax. A tourist tax could be implemented, modelled on tourist destinations such as Bhutan, and collected either on arrival at the airport, or as many tourists arrive over land, in the guesthouses and hotels. At the moment, a tourist tax of significance is only needed to visit nature conservation areas in Ladakh, which, however, has been very effective in creating revenues to protect such areas. Further, although organizations like LEDeG have mounted many awareness-raising campaigns on this issue, strong government support is needed to systematically curb possible over-consumption of water in Leh mainly by tourists. Water conservation strategies could also present innovative opportunities for eco-tourism. In any case, this study advocates an independent evaluation of which type of wastewater management system could be most beneficial for water resources conservation in Leh.

9 Conclusion: "If Not Now, When?"

The case of Leh Town, as it is facing large-scale pressure to take decisions concerning future development under climate change uncertainty, highlights the question of, as Primo Levi put it, "If not now, when?" It is human to tend to think that innovation is coupled with risk. But in a world of climate change, the opposite may be true: implementing "business as usual" options under uncertainty may

hold risk for us. Alternative and innovative approaches, which may be more flexible, may be more appropriate for dealing with uncertainty-related challenges. In particular, decentralized wastewater management seems to have much potential to address various aspects of water-related uncertainty. To foster innovation, courage by decision-makers is needed in order to lead the way on new sustainability pathways to be followed by others. With an appropriate vision, Leh has the full potential to become an international lighthouse example of an "ideal ecosociety".

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Authors Biography

Dr. Daphne Gondhalekar is an urban planner and Scientific Director of the Centre for Urban Ecology and Climate Adaptation (http://www.zsk.tum.de), Technical University Munich, Germany. Dr. Gondhalekar specializes in integrated urban planning, with focus on water and health in Germany, China and India. Previously, Dr. Gondhalekar worked as Senior Researcher at the Center for Development Research (ZEF), University of Bonn (2009–2013), at Environmental Planning Collaborative, an NGO in Ahmedabad, India (2008), and at the Department of Urban Studies and Planning at Massachusetts Institute of Technology (MIT) in Cambridge, MA, USA (2007–2008). She holds a PhD in Urban Planning from the University of Tokyo, Japan.

Dr. Sven Nussbaum works as a Project Manager at the German Aerospace Center (DLR) in the area of Technical Innovation in Business. He has over 10 years of working experience in Remote Sensing, Geodata and Information Systems. From 2011 to 2014, he worked as a Scientific Coordinator at the Center for Remote Sensing of Land Surfaces (ZFL) at the University of Bonn. Before that he was for 4 years GIS Team Lead at the International Atomic Energy Agency (IAEA) charged with task in the field of International Treaty Verification. His PhD dealt with the topic of object-based image analysis applied to critical security infrastructure.

Mr. Adris Akhtar is a Geographer with expertise in hydrology and GIS. He has worked with local as well as international NGOs in South Asia, in research and development practice, for the last 4 years. His research is based on extensive field work and has focused on urban human–nature interactions such as impacts of tourism on and health impacts of water resources.

Ms. Jenny Kebschull studied Geoecology at the TU Bergakademie Freiberg from 2007 until 2010 and continued her studies at the Department of Geography University of Bonn with focus on ecology, water, soil and geoinformation systems. Since 2010, she has been working for the Working Group for Agriculture, Water and Soil (http://www.alwb.de), the Center for Remote Sensing of Land Surfaces (http://www.zfl.uni-bonn.de) and Center for Development Research (http://www.zef.de) in the field of geoinformation systems, spatial data analysis and map design.