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Irrigation and Development in the Upper Indus Basin

Characteristics and Recent Changes of a Socio-hydrological System in Central Ladakh, India

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This article deals with the development of irrigated agriculture in the Upper Indus Basin of Central Ladakh in Northern India. Artificial irrigation, fed by meltwater from glaciers and snow cover, forms the backbone of regional food production in this semiarid Trans-Himalayan environment. Following an integrated socio-hydrological approach, we present 2 local case studies on the village level and an overview of Central Ladakh based on multi-temporal remote sensing analyses, qualitative interviews, and regional background information. The remote sensing analyses reveal both persistence and change of land use structures over the past 4 decades. In order to understand the characteristics and variations of this land use system, the role and influence of different stakeholders are analyzed. We show how land use dynamics reflect the interplay of local practices and external interventions in mountain development.

Keywords: *Irrigation systems; land use change; socio-hydrology; high mountains; Ladakh; Trans-Himalaya; India.*

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Introduction

The functioning and transformation of glacier-fed and snow-fed irrigation systems in the semiarid Trans-Himalayan and Karakoram Ranges have become a prominent research topic in recent years. Particular attention has been paid to the hydrological potentials and limitations of these "Asian water towers" on the one hand (Archer et al 2010; Immerzeel et al 2010) and to the social organization and practices of this land use type on the other (Kreutzmann 2000; Gutschow and Gutschow 2003; Aase and Veetas 2007). Adequate meltwater supply from glaciers or permanent snowfields in the upper catchments or, where local topographical conditions permit, direct abstraction from the main stream is a fundamental prerequisite for crop production under the prevalent semiarid climate in these regions.

The absolute quantity of water supply as well as the onset and duration of reliable runoff in relation to specific demands of the cultivated crops are critical factors for this agrarian production type (Kreutzmann 1998, 2011). The socioeconomic strand of research on irrigated mountain agriculture focuses on development issues such as resource management and distribution (Kreutzmann 2000), innovations, and food security (Dame and Nüsser 2011). Traditional irrigation systems are based on local institutions of water management, which include the construction and maintenance of the physical infrastructure, especially after natural hazards, and the organization of equitable water distribution among the land users. Moreover, various adapted technologies of water collection and storage have been developed to cope with the prevalent scarcity. However, local land use patterns have been modified and framed by external interventions under different political constellations, from colonial rule to the modern nation-states. A better understanding of how local irrigation and resource management systems are integrated in the broader mountain development process requires a consideration of political power and economic exchange relations between place-based dwellers and external actors.

Taking into account the various dimensions of water management in semiarid high mountain environments, it is important to analyze how these hybrid systems at the interface between natural resources and social response have been transformed, and to understand the forces driving this transformation. To assess the dynamics of irrigated land use patterns, some case studies based on a comparative bi- or even multi-temporal perspective have been carried out for adjacent mountain areas (Nüsser 2000, 2001; Gutschow and Gutschow 2003; Dame and Mankelow 2010). The objective of this article is to identify change and persistence of irrigated areas in the Upper Indus Basin of Central Ladakh (or Central Ladakh Basin) over the past 4 decades and to understand the role and influence of different stakeholders in corresponding development processes.

The mountain ranges of the Upper Indus Basin can be seen as a textbook example to explore the characteristics and variations of these human–environmental systems. After a concise overview of the environmental situation, our article addresses and illustrates the socio-hydrological complex of irrigated land use dynamics in a specific regional setting. Based on multi-temporal remote sensing analyses, qualitative interviews, and regional background information, we present 2 local case studies at the village level and an overview of the complete Central Ladakh Basin, south of the district capital, Leh. In the final section we examine the empirical results in the light of our theoretical considerations.

Regional socio-hydrological framework

We suggest a socio-hydrological approach for analyzing the dynamics of change in irrigated land use patterns in high mountain environments. The composite term "socio-hydrology" is used here to frame the complex human–environmental interactions of irrigated agriculture and development processes within the mountain region of Ladakh. To conceptualize the interplay of specific hydrological conditions and dynamics, socioeconomic development, institutional arrangements, and external interventions, there is a need for a research perspective beyond simple deterministic causalities. In their attempt to theorize about the complex of biophysical issues and catchment management, Falkenmark and Folke (2002: 4) have stressed the need to accept change as "an integral part of the development of natural and human dominated landscapes and societal development." They call for a paradigm shift toward integrated analyses of hydrological processes and societal response. A better understanding of the specific development trajectory needs to integrate the constellation of relevant stakeholders together with their specific concurrent—or sometimes conflicting—development agendas and strategies. Departing from this research perspective, we include the place-based village population and the partly non-place-based government and nongovernmental organizations (NGOs) in the analysis.

Local communities in Ladakh continue to subsist on irrigated cultivation to a considerable extent. At the same time, changes in the importance of mountain agriculture resulting from increased off-farm income opportunities, improved accessibility, and subsidized food supplies are evident. Although peasants' economic choices show a certain flexibility, land use practices are characterized by a high degree of stability and continuity. Their agricultural production is well adapted to the environmental resource potentials. At the same time, livelihood security and well-being, including resilience toward natural hazards and other unpredictable shocks, can be identified as the main aspirations of local mountain dwellers (Dame and Nüsser 2011).

Ladakh: a high-altitude desert region

Environmental setting

Bordered by the Great Himalayan and Karakoram ranges, Ladakh is located in the northernmost Indian state of Jammu and Kashmir. In Central Ladakh, the Indus Valley appears as a wide basin between the villages of Kharu in the southeast and Phey in the northwest, where the Indus flows over a large floodplain at an altitude between 3300 m and 3100 m. The Upper Indus Basin at Leh is bounded by the Ladakh Range to the north and the Stok Range to the south (Figure 1). The steep slopes are dissected by numerous tributary valleys, some of them without perennial runoff, terminating in large alluvial fans, where almost all scattered settlements are located. Only a few villages, such as Stakna and Chushod, occupy favorable areas close to the Indus River.

Because of the rain shadow effect of the Himalayan Range, mean annual precipitation in Leh (3506 m) totals less than 100 mm, and there is high interannual variability. Whereas the average summer rainfall between July and September reaches 37.5 mm, the average winter precipitation between January and March amounts to 27.3 mm and falls almost entirely as snow (Archer and Fowler 2004). The mean annual temperature is 5.6°C, and the thermal range is characterized by high seasonal variation. During January, the coldest month, the mean temperature drops to −7.2°C (IMD 2011). Despite these low temperatures, only the upper tracts of the mountains receive a continuous winter snow cover, whereas the lower valleys get snow for a few days only. During August—the warmest month—the mean temperature rises to 17.5°C (IMD 2011). The factors determining water supply in summer are the high-altitude glaciers, located above 5200 m, and in some cases seasonal or perennial snowfields. Because of the semiarid conditions, the glaciated area is very small, and cirque glaciers smaller than 1 km^2 are dominant (Schmidt and Nüsser 2012).

Irrigation systems

In combination with animal husbandry, agriculture forms the basis of livelihood and food security in the permanent settlements of Ladakh (Dollfus et al 2009; Dame and Nüsser 2011). Agriculture depends entirely on gravity-controlled irrigation and concentrates on the cultivation of the staple crops: barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*). Peas, mustard, potatoes, carrots, turnip, radish, green leafy vegetables, and alfalfa (*Medicago* spp) are also regularly cultivated on terraced fields, accompanied by apple and apricot trees. Furthermore, plantations of poplars (*Populus* spp) and willows (*Salix* spp) are characteristic elements of the irrigated areas, covering the local demand for fuel and timber wood.

Depending on the origin of irrigation water, 2 types of irrigation systems can be distinguished in Ladakh, as first described by colonial European travelers (Moorcroft and

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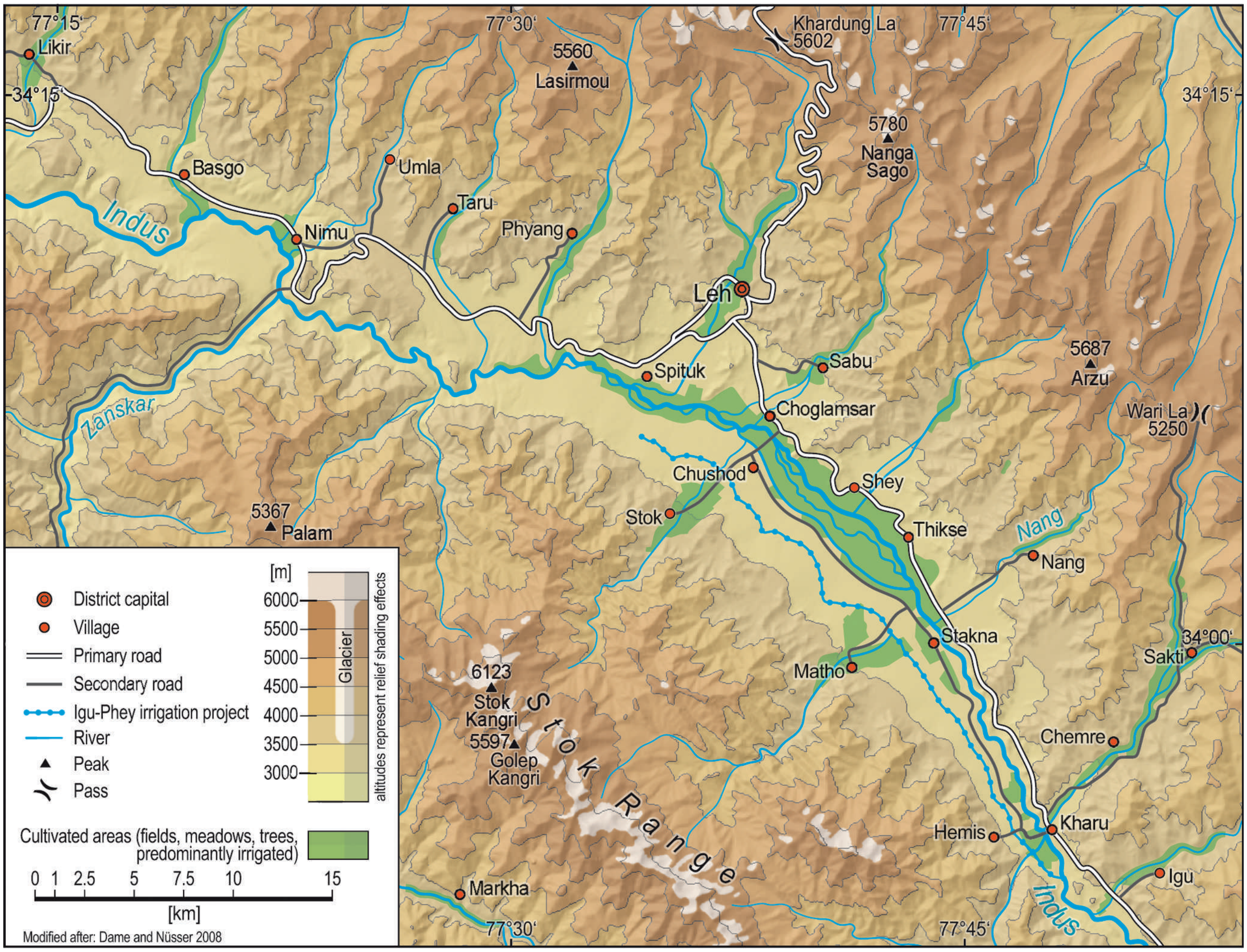
Figure 1 The Upper Indus Basin of Ladakh. (Draft by Juliane Dame and Marcus Nüsser; cartography by Nils Harm)



Trebeck 1837; Cunningham 1853): the snow- and glacier-fed irrigation systems in the tributary valleys and the system in the main valley, where water is directly abstracted from the Indus River. The cultivated areas along the tributaries are adapted to the hydrological conditions and catchment sizes for distributing water between households efficiently and equitably on a rotational basis (Gutschow 1998; Vohra 2000). The frequency of irrigation depends on inter- and intra-annual water availability. Severe water scarcity may occur during the sowing period in April and May as a result of snow-poor winters or delayed snowmelt (Labbal 2000). Glaciers provide most of the runoff in summer, with a maximum regularly reached in the afternoon. In such water surplus situations, the evening and nighttime runoff is usually stored in reservoirs (*zing*) and diverted to the fields in the morning, when the natural runoff is scarce.

Contrary to the situation in the tributaries, the Indus-based irrigation network is not prone to water scarcity and thus no rotational system for water distribution is required. Despite potential flood risk, the vast floodplain of the Indus forms the largest area under cultivation in the whole of Ladakh. Here, one can find extended patches of sea-buckthorn (*Hippophae rhamnoides*) along the water course. The irrigated fields are located on banks at the edge of the braided stream, and water is diverted from the Indus by embankments and inundation channels. During colonial times these riverbanks were exclusively used as pastures (Cunningham 1853: 221). However, already under the British rule a certain enlargement of the cultivated area, on the Indus floodplain close to Spituk, is documented (Kaul and Kaul 2004).

Data and methods

Based on the aforementioned theoretical framework, we chose a multi-methodological approach to analyze the recent development of irrigated agriculture in the Central Ladakh Basin. We combined remote sensing methods supported by field surveys and social research methods. After a reconnaissance survey in 2007, 2 field

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campaigns were carried out in 2008 and 2009 to obtain a detailed empirical basis and photographic documentation for the interpretation of satellite data. As historical maps, photographs, and comprehensive statistical land use data were not available for different time periods on the village level, a multi-temporal and multi-scale remote sensing approach was considered appropriate for the research aim. After standardized procedures of georeferencing and co-registration of all analyzed satellite data, visual image interpretation was used for mapping. Individual land use and infrastructure elements were classified and manually digitized on screen, using a geographic information system.

For the detailed case studies in the tributary valley of Stok and in the Indus Valley, a panchromatic Corona image (30 July 1969) from the early US military reconnaissance satellite and a pan-sharpened Quickbird image (17 July 2006) were used. Supported by the field investigations, the orthorectified high spatial resolution imagery allowed for the bitemporal mapping of small-scale land use structures and infrastructure elements. In order to analyze the decadal changes of the irrigated areas on the regional scale of the complete Central Ladakh Basin, we integrated 8 Landsat and 3 Spot scenes together with the aforementioned Corona and Quickbird data. This approach allowed us to identify the extension of cultivated areas between 1969 and 2009. To detect the different construction phases of the Igu-Phey irrigation project—a major water diversion scheme—the channels were manually digitized on all satellite images.

Qualitative interview data, unpublished project information, and official statistical records were gathered in Leh between 2008 and 2010. Interviews with experts from NGOs and government organizations were informal in nature to make sure that core topics were covered with each informant, while allowing the interviewers to pursue further areas of interest arising from the conversation.

Recent changes in irrigated land use

Changes in small tributaries: the example of Stok

The example of the village of Stok, located south of Leh, illustrates the development of irrigated land use in the tributary valleys of Ladakh. Because of the north-facing orientation of the tributary, the settlement (Figure 2) of 1321 inhabitants (TISS 2006), ranging from an altitude of 3370 to 3670 m, is prone to regular water scarcity in spring. Between 1969 and 2006, the total utilized area expanded from 3.5 km^2 to 4.4 km^2 (Figure 3). In 1969, more than half of the irrigated area was used for the cultivation of crops and fodder plants, and merely 11% was temporary fallows or abandoned land. The tree plantations covered only 5%. However, in contrast to other villages, some small forests with old trees exist in the vicinity of the palace of the former Ladakhi king. In 2006, the pattern of terraced fields still existed almost in the same form; not many fields had changed in shape and size compared to 1969, whereas the mean field size decreased from 732 m^2 to 613 m^2. The number of houses and sacred buildings (*chorten*, mani walls) increased from approximately 250 to more than 700. However, in the same period, the number of households only increased from 205 to 232 (Census of India 1973; TISS 2006). The bitemporal comparison reveals a growing number of fallows and abandoned fields, possibly because of new income opportunities, mainly in the booming tourism sector, the government, and the army.

The location of Stok, in close proximity to the district capital and at a starting point of one prominent trekking route, offers several off-farm employment opportunities. The growing number of households involved in non-agrarian activities leads to a lack of—especially male—a workforce in the agricultural sector. In many cases, households choose to employ off-farm laborers, and others decide to leave a portion of their land fallow. Moreover, we identified brick production for houses as another important reason for the abandonment of fields.

Because of the massive afforestation, partly cultivated for market purposes, the tree-covered areas doubled. The enlargement of the cultivated area is generally restricted by the topographical situation, and only the gently sloped locations, covered with alluvial sediments, can serve as arable land. Already in 1969 new land was developed at the valley outlet and on the right slopes. These new cultivated areas were mainly used for pasture and cultivation of fodder. Between 1969 and 2006 the irrigated area expanded by 0.9 km^2, but there were no changes in the former spatial distribution pattern.

Changes in the Indus Valley: the example of Chushod and Choglamsar

In order to analyze the development of cultivated areas in the Indus-based irrigation network, we present portions of the irrigated areas of 2 villages: Chushod (3220 m), with a population of 5083 (TISS 2006), and Choglamsar (3220 m), with 2632 inhabitants (TISS 2006). In 1969, any expansion of cultivated area on the islands of the braided stream was difficult because of the prevailing flood risk and the lack of financial support to divert water to higher parts. However, already in 1969, one can detect part of a 20-km long channel under construction on the right bank of the Indus (Figure 4).

This massive infrastructure was built to offer cultivatable land to more than 7000 Tibetan refugees who came to Ladakh after the Sino–Indian war and were settled in new communities adjacent to Leh (Goodall 2004; Sahni 2007). According to the Census of India (1971), 92 households were counted in Choglamsar occupying an envisaged area of about 3.64 km^2. The extension of irrigated area mainly took place in the 1990s and enlarged the agricultural basis of the refugee settlement. This area is characterized by small regularly shaped plots with an

Figure 2 Village and irrigated land of Stok, located on an alluvial fan of a tributary valley with the partly glaciated Stok Range in the background. (Photo by Marcus Nüsser, 28 August 2009)

average size of 160 m^2, which are predominantly used for fodder production. By contrast, the field size in Chushod amounted to approximately 620 m^2 in 2006, which was reduced from 775 m^2 in 1969. In the same period the numbers of fallows, abandoned fields, and tree plantations increased (Figure 5). Furthermore, a drastic increase in houses, especially of sacred buildings due to the residence of the Dalai Lama, can be observed.

As in the example of Stok, some of the fallows are used for the extraction of clay bricks as house-building material. The development between 1969 and 2006 described here occurred in parallel with the transformation of the braided Indus into a meandering river system through the construction of barrages and embankments blocking former side rivers and stabilizing undercut slopes. These measures, together with new inundation channels, served to reduce annual flooding. Trees are now growing on the former stream islands, and large green grounds, used for the ceremonies of the Dalai Lama and for public entertainment, have been established. In contrast to Choglamsar, the example of Chushod shows no significant enlargement of the cultivated area.

Development on a regional scale: the Upper Indus Basin of Central Ladakh

We present the development of irrigated agriculture in the whole Upper Indus Basin of Central Ladakh in order to place the 2 local case studies in a regional context. The

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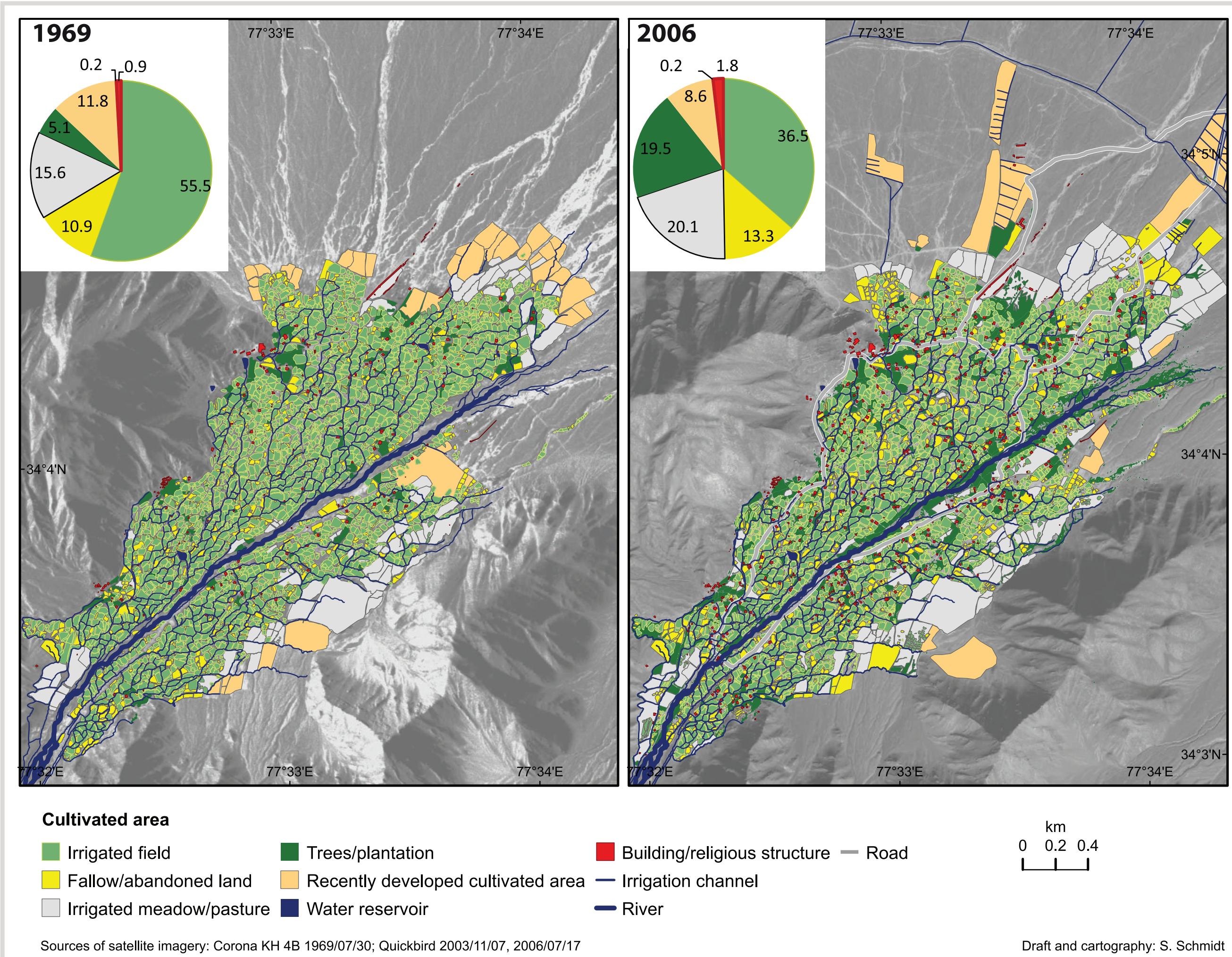
Figure 3 Development of the cultivated area in Stok between 1969 and 2006. (Draft and cartography by Susanne Schmidt)



complete area under irrigation in the Indus Valley and its tributaries, including field crops and tree plantations, increased by 14%, from 88 km^2 in the late 1960s to 100 km^2 in 2009. Major land cover change from barren to cultivated land is detectable in the Indus Valley along the braided stream and on the alluvial fans. In comparison, the extension of irrigated area in the tributary valleys is only of minor importance (Figure 6).

A significant increase in large trees and shrubs can be observed in all investigated areas. This confirms earlier observations by Fox et al (1994), who assume "a long-term recovery from the massive destruction of woodlands associated with the Kashmiri occupation of Leh around 1840, exacerbated by the increased government and army demands soon after independence and before the Leh–Srinagar road opened in 1962" (Fox et al 1994: 53).

The most massive intervention in the development of irrigated areas in Central Ladakh has been effected through the government-funded Igu (alternatively, Igo)-Phey Irrigation Project, which was launched in 1979. During the construction of the 43-km-long main channel diverting Indus water to barren but arable land along the south side of the Indus Valley (Figure 6), extreme efforts were necessary to compensate for different heights, bridge small rivers, and protect the channel against flash floods and sedimentation. More than 30 distributaries should divert water from the main channel to the fields (GJK 2007).

The objective of this scheme is a total increase of 4370 ha in cultivatable area in the basin, expanding the total irrigated area of the whole Leh district from approximately 100 km^2 to 140 km^2. A second goal is the improvement of energy supply by constructing a hydro-power station with an estimated capacity of 3 MW at Martselang. This ambitious project has experienced significant delays in construction. Whereas more than half of the main channel was already build in 1986, its final completion did not take place until 2000. The same holds true for the construction of the distributaries. As a result, only 20% of the area has been terraced, and less

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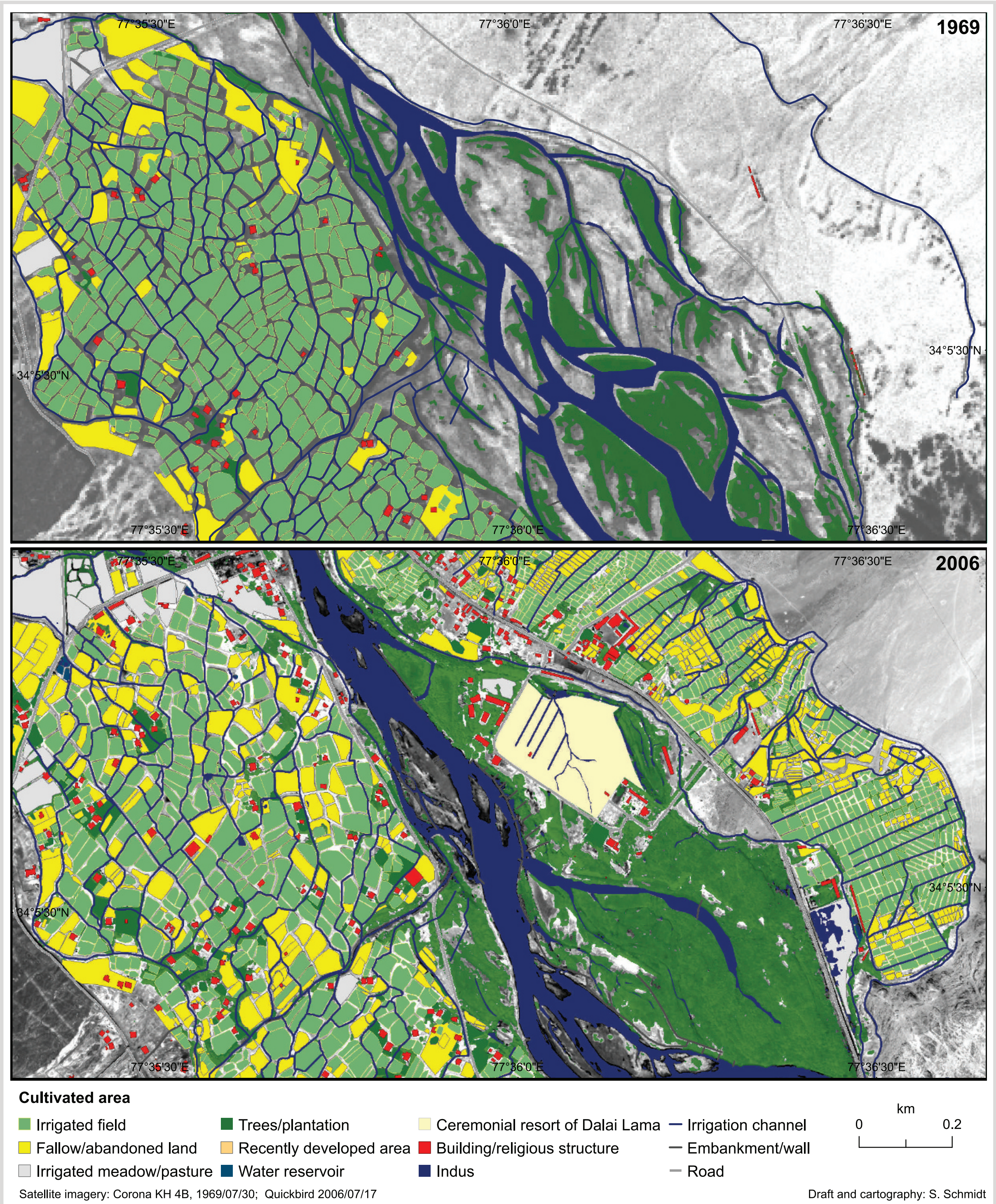
Figure 4 Development of the cultivated area in sections of Chushod and Choglamsar between 1969 and 2006. (Draft and cartography by Susanne Schmidt)



than 2 km^2 of the planned irrigated area was under cultivation in 2007 (GJK 2007), more than 30 years after approval. The interpretation of satellite imagery confirms these figures and shows that only 12 km^2 have been parceled in individual plots (Figure 6). However, most of the area is still not under cultivation. The involved authorities named delays in the allocation of land to farmers as a main reason.

In addition, in the summer of 2006 flash floods affected the irrigation project, especially at Chushod. Our

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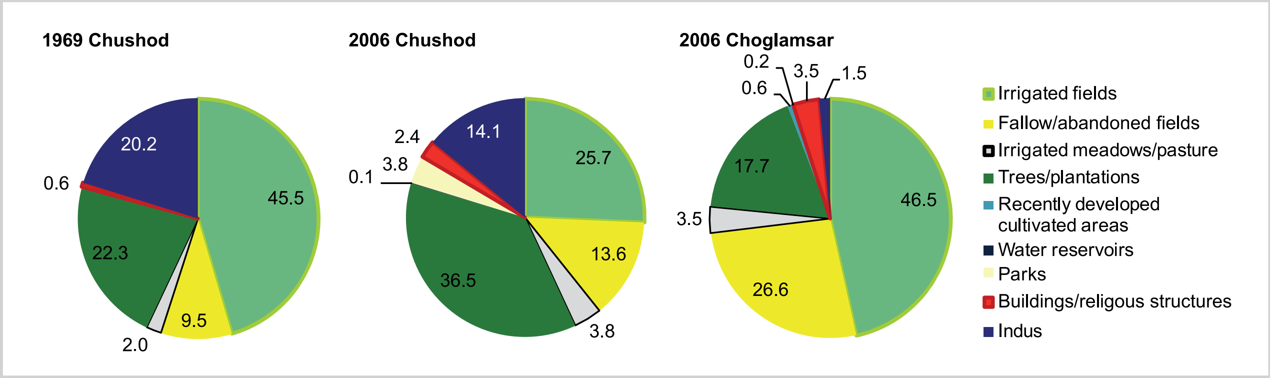
Figure 5 Quantitative changes in the cultivated area in sections of Chushod and Choglamsar between 1969 and 2006.



field investigations in 2009 confirmed that due to several leakages and cracks, the areas below the cemented main channel receive unused seeping water, especially between Matho and Chushod, so that the channel tail runs empty. Currently, most of the area under cultivation near Stakna is used by the Agricultural Research Station SKUAST for tree nurseries and fodder plants and by the Department of Animal Husbandry.

Land use dynamics: the impact of government and nongovernment actors

Since independence, the government of India has launched several programs to increase agricultural productivity and foster economic modernization in the Himalayan borderlands (Rahul 1968; Mohan 2005). Since becoming an administrative part of the Jammu and Kashmir state, Ladakh has turned from a central point in the Trans-Himalayan trade to a geopolitical borderland. Thus, the development efforts by the Indian central government also serve the strategic interest of intensifying the integration of this sensitive border region in the Indian nation-state (Dame and Nüsser 2008; van Beek and Pirie 2008). More recently, struggles for autonomy have also aimed at fostering the implementation of development programs in the region. In the past 2 decades, Ladakhis have received recognition as scheduled tribes, and Leh district has been granted a semiautonomous hill council (Ladakh Autonomous Hill Development Council, LAHDC) (van Beek 2001). Currently, development programs are shaped by government actors at the national, state, and district levels.

One of the most prominent examples of intervention schemes is the National Watershed Development Program (NWDP 2009), which was initiated in Ladakh in 1995 for the purpose of integrated rural development, including expansion and improvement of irrigation infrastructure, agrarian innovations, and afforestation. Apart from government agencies, different NGOs became relevant actors in the development arena through this scheme. Under the umbrella of the Watershed Development Program, various NGOs started to carry out activities at the local level as project implementing agencies (PIAs). This operational structure led to a mushrooming of new NGOs in Leh, which hoped to benefit from available money flows.

A few years back, struggles between the different stakeholders, in combination with the subsidized nature of the program, created a situation without accountability or trust (Mankelow 2003). Recently, the latest *hariyali* (greening) program was introduced with reformed guidelines for watershed development. In this context, the responsibility for project implementation shifted from the NGOs to dedicated government agencies under the LAHDC. In practice, however, the mode of operation continues to build on NGOs and added government agencies as new PIAs. These evoked new struggles between the involved stakeholders. Some NGOs blamed agencies for not being functional and having weak ties to the villages.

Both under the Watershed Development Program as well as under *hariyali*, different activities have been realized at the village level. In contrast to the Igu-Phey Irrigation Project, the focus is on small-scale measures and participatory approaches. Locally elected committees in the villages choose activities such as the creation and restoration of water channels or the construction of water reservoirs for improved water distribution. Villagers have benefited from the monetary remuneration of such community tasks, which have helped to keep the irrigation infrastructure functional and have fostered continuity in land use patterns.

Although the watershed development schemes are designed by government agencies, some NGOs support innovations in resource management systems through knowledge and technology transfer. Among them, the Leh Nutrition Project (LNP) has a leading role in promoting particular water-harvesting constructions that aim at reducing water scarcity in the critical sowing period. The most prominent examples are the so-called artificial glaciers (Norphel 2007), which are constructed in selected tributaries of the Indus and consist of small parallel stone

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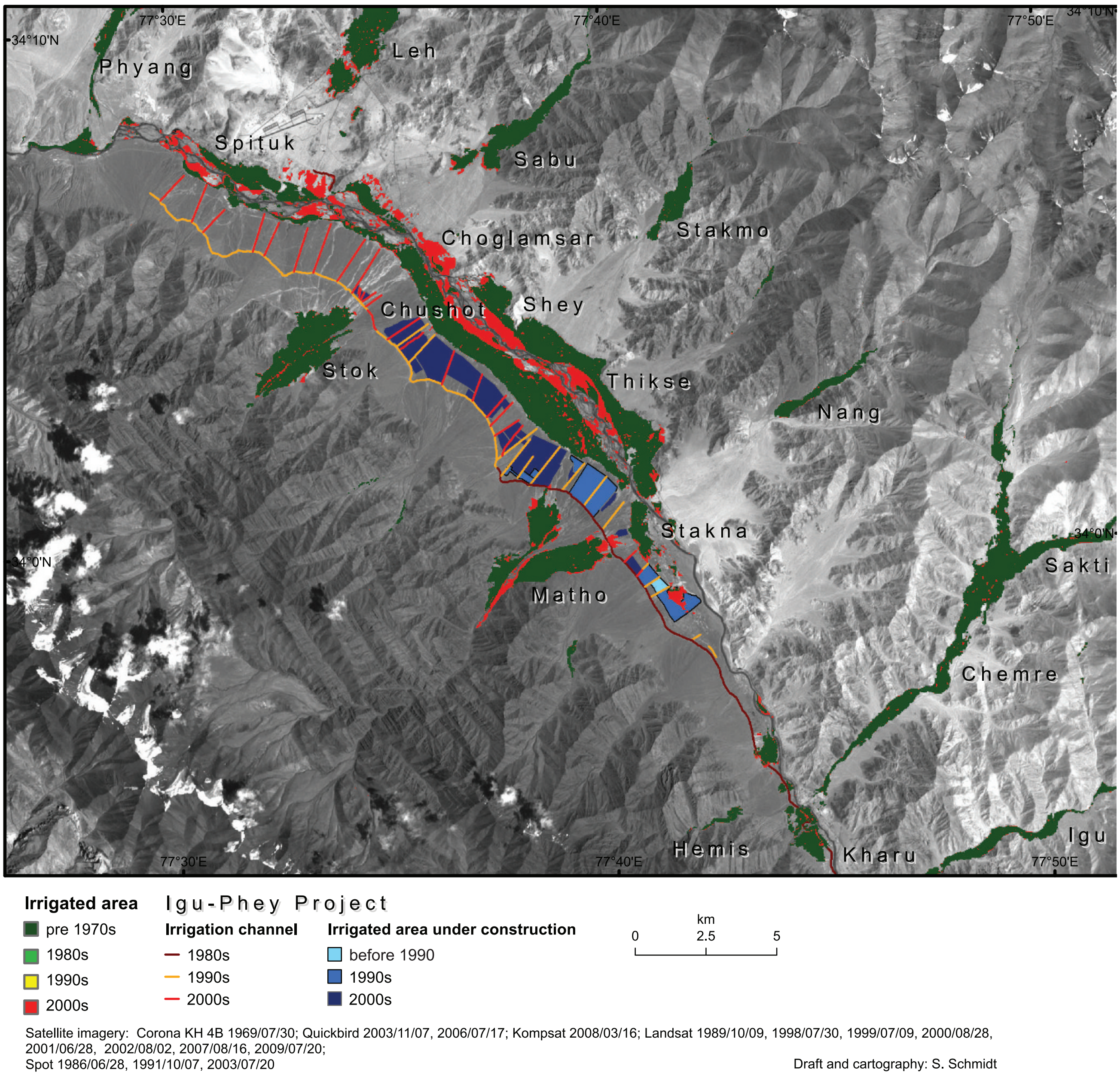
Figure 6 Development of irrigated areas in the Upper Indus Basin of Ladakh with construction phases of the Igu-Phey Diversion Project. (Draft and cartography by Susanne Schmidt)



walls across the watercourse to store water in the form of ice during winter. The principle of these constructions is that water freezing can be induced by reducing the runoff velocity, a phenomenon known in hydrology as "icing." The artificial glaciers are located above the cultivated lands and below natural glaciers at altitudes between approximately 3900 and 4600 m. Here, melting in spring starts early and increases water availability for the fields.

The case of the artificial glaciers also highlights a shift to new modes of funding. These projects were originally run under the Watershed Development Program; now the Indian Army, with its Operation Sadbhavna (Goodwill) Program, has become a new actor in the development arena. A large number of troops have been stationed in Ladakh since the Sino–Indian war over the Aksai Chin Plateau in 1962, and the Kashmir wars with Pakistan in 1965, 1971, and 1999 in the Kargil district (Aggarwal 2004). In the aftermath of the Kargil war, the civil–military Operation Sadbhavna was introduced as a development and welfare initiative (Aggarwal and Bhan 2009). Among the various activities, the initiative started funding the construction of an artificial glacier with LNP in 2008.

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Despite the struggles between the different stakeholders, the interventions have affected the Ladakhi "socio-hydroscape." Despite the diverse efforts of the civil bureaucracy and the army to upgrade the regional infrastructure, accessibility and communication facilities are embedded in the primary ambition of regional integration. The resulting improvements have created important development incentives for the mountain people of Ladakh. Designed by external organizations often aiming to meet the needs of the entire country, the interventions shape the rooms to maneuver for local actors and their livelihood strategies. However, their impact is not unilinear, as the local communities negotiate development on the ground and adapt their strategies in the context of changing conditions in a flexible manner. Local farmers adopt external assistance and new techniques while relying on traditional knowledge and institutions at the same time. Thus, despite large-scale irrigation projects, a growing number of people are abandoning their fields and diversifying their household activities.

Discussion

The analysis of irrigation systems in Central Ladakh shows that the situation in the different cases reflects the intensity of external influences and development interventions. Both persistence and change of land use structures can be detected next to each other. For a better understanding of development processes, it is important to integrate the aspirations and perspectives of various stakeholders. Although a first glance at quantitative and visible land use dynamics in the selected settlements would suggest change due to population increase, the study shows that modifications in the hydrological pattern can only be fully understood by taking social change and local political economy into account.

On the one hand, continuity and persistence of the land use pattern with limited fragmentation and minor enlargements of the irrigated area can be observed, as the examples of Stok and Chushod show. The land use strategies of Ladakhi villagers are characterized by their efforts to improve livelihood security through flexible integration of subsistence-based agriculture and off-farm activities. In this context they respond to new challenges while relying on their primary pillar. On the other hand, socioeconomic factors, such as a reduction of the available workforce and increased monetary income, have led to a reduced share of fields under crop cultivation and an increase in fallows and extensive tree plantations. The local community of Stok manages to maintain the subsistence-oriented water diversion system in a sustainable manner. Development interventions aimed at modernization and economic productivity are implemented to enhance water management and foster the maintenance of this system at the same time.

The second in-depth investigation of Chushod and Choglamsar shows distinct changes over the observation period. Here, migration of Tibetan refugees and nomads from the Changthang Plateau in eastern Ladakh to settlements near the regional capital Leh has induced striking change. These processes have been framed by massive development interventions to support the migrants. Regarding the future of the Central Ladakh Basin, the expansion of settlements in the proximity of Leh is a major factor; this has not been a focus of this article, however. Another characteristic trend is the increasing utilization of the Indus floodplain that solely served as pastureland until the 1960s. This trend is likely to continue in the future. The impact of the Igu-Phey Irrigation Project on regional development remains an open question.

Conclusions

The different examples from Ladakh have highlighted how hydrological processes are coupled with social change and certain aspects of the local political economy. In order to frame the array of irrigated agriculture in the context of regional development, the complexity of environmental and socioeconomic aspects has to be taken into consideration. The proposed socio-hydrological framework encompasses all dimensions and factors that are crucial for an integrated analysis of irrigated land use patterns and corresponding land cover changes. The intensity and dynamics of resource management in peripheral mountain regions do not accurately reflect the spatial (and temporal) availability of natural resources. A whole set of socioeconomic aspects, political constellations, external impulses, internal reactions, and rooms to maneuver shape regional development paths. We would also like to add that scenarios of future development become more plausible and persuasive if they include a retrospective approach.

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