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Energy and Land Use in the Pamir-Alai Mountains

Examples From Five Social-ecological Regions

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In a comparative study of energy resources and energy consumption patterns in the Pamir-Alai Mountains of Kyrgyzstan and Tajikistan, the relations between energy consumption, land use, and livelihoods were investigated. An approach that presents energy flow through an ecosystem was developed, in particular to highlight ecosystem services and the scope of action for human interventions in the energy-land management nexus. Qualitative data were collected during a field study in October 2009 through household interviews and group discussions. Based on the relationship between energy supply and ecosystem services, typical village profiles depicting the flows of energy and financial assets are presented that illustrate the relation between energy resources, land use, and livelihood assets. The household interviews reflect situations in the different villages and allow a distinction to be made between the energy consumption patterns of poor and wealthier families. This case study in the Pamir-Alai Mountains emphasizes that a reappraisal of energy as a central focus within mountain ecosystems and their services to the population is necessary for both ecosystem preservation and poverty reduction.

Keywords: *Mountain ecosystems; energy; sustainable land management; rural development; ecosystem services; Central Asia.*

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Introduction

The High Pamir and Pamir-Alai Mountains are located in the Central Asian countries of Kyrgyzstan and Tajikistan. With their many glaciers and peaks of more than 7000 masl, the mountains constitute the "water tower" of Central Asia. Their unique ecosystems range from deeply incised valleys with fertile valley bottoms to arid high plains where only few plants specifically adapted to the climatic conditions can survive.

Kyrgyzstan and Tajikistan are former Soviet Republics that have been independent since 1991. The collapse of the Soviet Union had manifold consequences for both countries that led to economic stress, widespread poverty, and political instability (Breu and Hurni 2003). The energy sector was greatly transformed, since the supply of fossil fuels from neighboring countries was drastically reduced and the mining volume of own fuel deposits decreased. For example, in Tajikistan, less than 5% of the 1991 value of coal was consumed in 2006 (TJ 2008; KZ 2009). In the mountain areas considered in this study, 2 aspects are of special interest: (1) The large centrally controlled state farms were dismantled, and people in mountain communities now rely on subsistence agriculture on small farms and on livestock husbandry (for a discussion of post-Soviet land-use reforms see Herbers 2003). (2) Along with state employment, state subsidies for and supply of fossil fuels were reduced; hence communities began to rely to a large extent on the local ecosystems to satisfy their energy demands, resulting in widespread deforestation and land degradation in the region (Droux and Hoeck 2004; Hoeck et al 2007).

Mountains with harsh environments, and their underutilized potential for renewable energy resources such as hydropower, geothermal, solar, and wind energy, play a special role that deserves considerable attention. General issues pertaining to energy in mountain areas are discussed in the literature (eg Schweizer and Preiser 1997), but few studies focus directly on the energy problems of the Pamir-Alai Region. In particular, in the context of forthcoming transformations of energy sectors on a global level and the related global energy crisis, Central Asia is an important region, as it has been facing energy problems and dealing with energy scarcity for a long time. Droux and Hoeck investigated in detail the energy resources of several villages in Tajikistan in a partially quantitative manner and emphasized that the energy situation was crucial to the development of the region (Droux and Hoeck 2004; Hoeck et al 2007).

In order to explore the scope of action for conservation of ecosystems and improvement of the livelihoods of rural communities, it is important to understand which energy resources are available and how they are used, and to investigate the relations between energy, land use, and socioeconomic factors. Our approach, presented below, focuses on a general framework of energy as an ecosystem service and on a qualitative investigation of the strategies of the rural population, as well as on their future options for improving their livelihood.

Overview of ecosystems and energy resources

The ecosystems of the Pamir-Alai Mountains can be divided into 3 major subregions (Breu and Hurni 2005): (1) In the Western Pamirs, deep valleys are surrounded by peaks of over 7000 m, and water scarcity and harsh temperatures (down to −30°C) constrain biomass production. (2) The Eastern Pamirs constitute an arid high plateau with smooth topography at 3500–5500 m, where the high mountain desert soil supports only dwarf shrubs that are adapted to minimal precipitation (70 mm annually) and a short vegetation period with only 60 nonfreezing days yearly. (3) The Alai Mountains are characterized by continental high mountain conditions with dry and warm summers and very cold winters (temperature ranges from −30°C to 32°C); only about 1% of the area is cropland.

Mountain areas constitute a particular situation with respect to energy resources, due to extreme environmental conditions, weak infrastructure, dispersed settlements, and their general remoteness (Schweizer and Preiser 1997). In the Pamir-Alai Mountains, depending on the location and local conditions, a household in a mountain village may have access to coal, electricity, firewood, and livestock dung for energy purposes. Firewood and dung come directly from the surrounding ecosystems, while fossil fuels, and in most cases electricity, are external inputs. In the Pamir Mountains in Tajikistan, an average of 80% of the overall energy demand is met by traditional biomass such as firewood and dung (Breu and Hurni 2003). As described above, the climatic and topographic conditions allow only sparse vegetation to grow. Many villages at higher altitudes (the tree line is at around 3700 m) cannot rely on forest ecosystems but instead exploit pastures and low shrub vegetation. Deforestation and desertification are frequent phenomena in the region (Aknazarov 2003).

In Kyrgyzstan, coal mines are exploited in the Alai Mountains, and coal is locally available in the villages, while in the Pamir Mountains in Tajikistan, the supply of coal in remote villages is scarce. In both countries, electricity at the national level is mainly generated by hydropower (IEA 2008). The access and reliability of electricity supply depends greatly on the remoteness of a village. In Kyrgyzstan, basically every village is connected to a central electricity grid, while Tajikistan has several separate grids. For some settlements, small local grids exist, and a number of villages have no connection to transmission lines at all (Jedemann 2011).

Ecosystem services

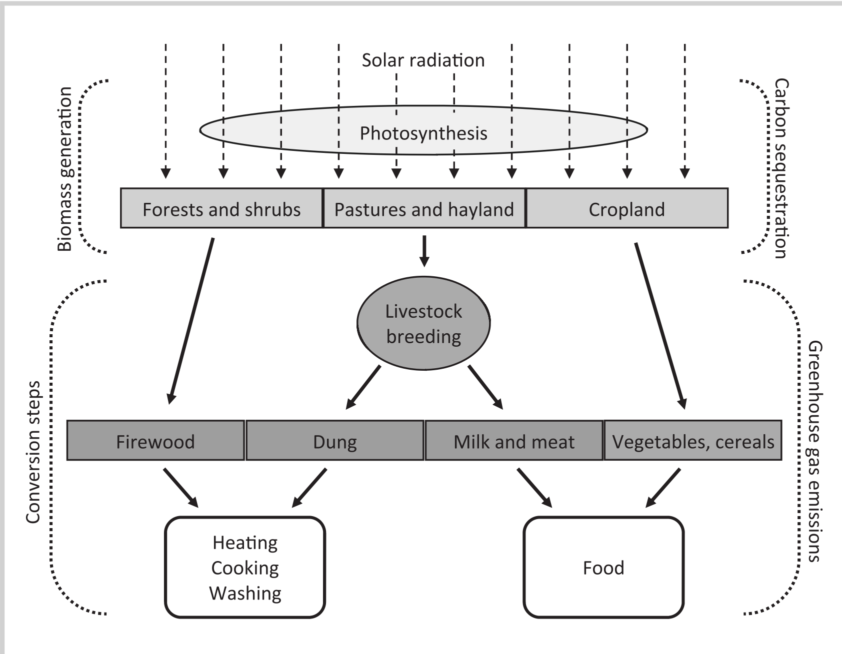
The concept of ecosystem services (MEA 2005) is useful when investigating energy and land use. Ecosystem services are classified into 4 categories: provisioning services such as food, freshwater, and fuelwood; regulating services such as water purification or disease regulation; cultural services, which include cultural heritage and aesthetic benefits; and supporting services such as soil formation, nutrient cycling, and primary production itself. The Millennium Ecosystem Assessment (MEA) provides a useful framework that connects ecosystem services to human well-being in terms of the following 5 components: (1) basic material for a good life, (2) health, (3) good social relations, (4) security, and (5) freedom of choice and action. The MEA distinguishes indirect and direct drivers that affect ecosystem services. Indirect drivers are demography, the economy, sociopolitical influences, religion, and technology, while examples of direct drivers are land use and land cover, use of technology, external inputs, harvest and resource consumption, and climate change. Using the MEA framework, one can evaluate the impacts of the collapse of the Soviet Union in the region. This brought forth rapid changes and transformation in every aspect of both the direct and the indirect drivers (Shigaeva et al 2007).

The ecosystems in the Pamir-Alai Mountains suffer from severe land degradation, in particular deforestation, erosion, landslides, overgrazing, declining productivity, and desertification (Breu and Hurni 2005). All these affect the functioning of ecosystem services. The consequences are a decline of provisioning services and degradation of regulating and supporting services, together with increased poverty—for example, a decrease of the capacity to cope with natural hazards and decline of biodiversity. Energy is a very central aspect in the nexus of ecosystem services, rural livelihoods, and land degradation, as detailed below.

Conceptualization of the energy–landuse nexus

In order to highlight the role of energy in the context of ecosystem services, it is useful to look at how energy is transformed within a particular mountain ecosystem, and how it is made usable and consumed. Following the principles of energy flow within biological and agricultural systems (Casimir 1991; Zwölfer 1991), Figure 1 was developed to represent the coupled social-ecological system, with a focus on energy flow through ecosystems. Solar energy is transformed into chemical energy via photosynthesis and stored in living biomass. Within the ecosystems in the Pamir-Alai Mountains, 3 main land-use categories with different energy content can be distinguished: forest (including shrubs), pastures, and cropland. The main end use of energy in rural communities is heating, cooking, and washing (thermal energy corresponding to exosomatic metabolism) and food (dietary energy: endosomatic metabolism). The energy content of food consumed is considerably less than thermal energy. However, by contrast with firewood and dung, which in many cases are noncommercial, it also

FIGURE 1 The energy flow through an ecosystem in the Pamir-Alai Mountains. Here only the energy generated within ecosystems is considered. Top: biomass generation; bottom: end use, that is, thermal energy and food. For each land-use category and end use, different conversion steps are necessary. Livestock breeding plays an important role as it transforms the energy stored in grassland into food products and dung. The scheme allows definition of the scope of action for increasing the efficiency of the different conversion steps. Of importance are sustainable land management and good practices in livestock breeding, along with increasing energy efficiency through better stoves and thermal insulation.



has a market value and constitutes an important driver for land-use strategies. Depending on the land-use category, there are different conversion steps for meeting the end use:

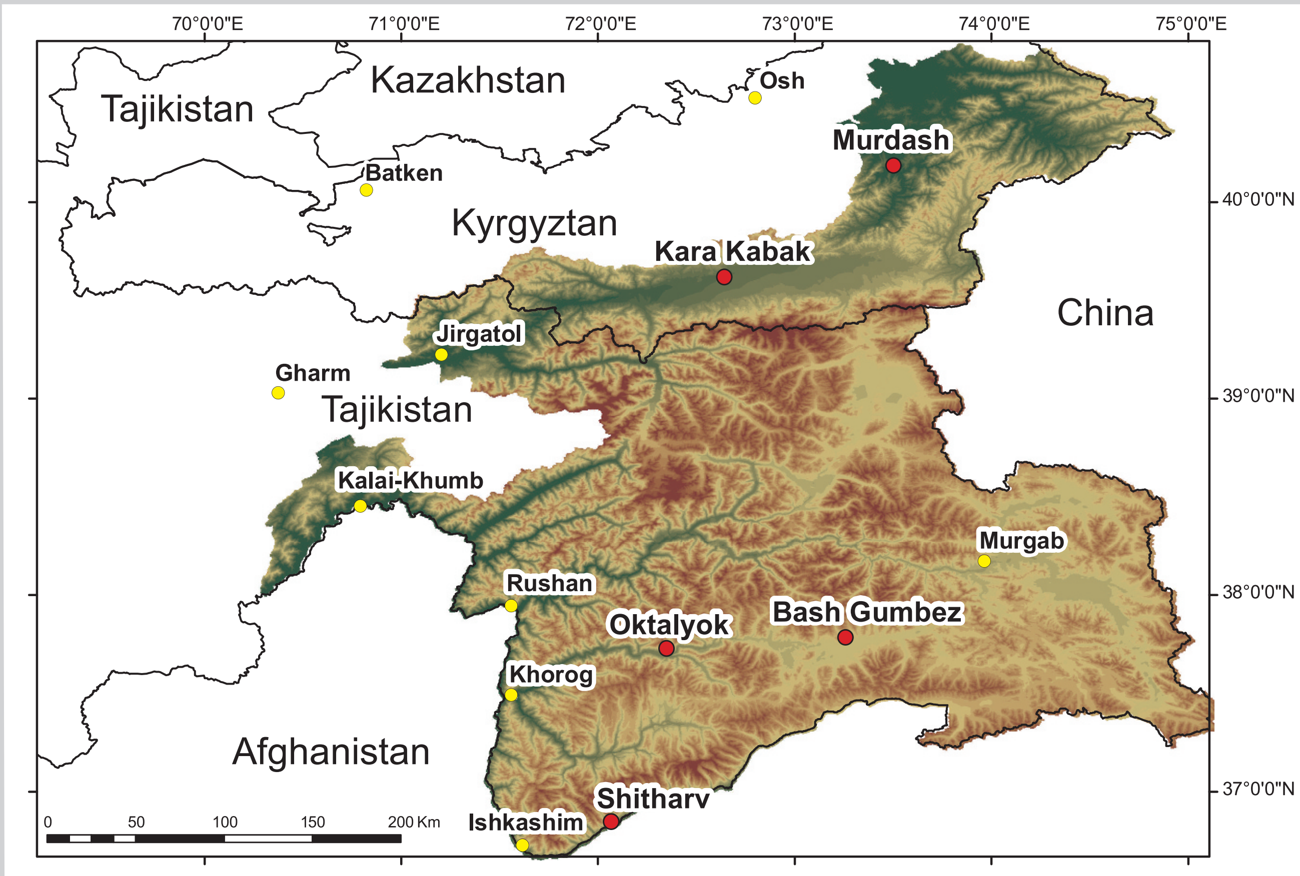
- Firewood extracted from forest or shrubland needs to be dried to optimize its fuel value, and in addition, the efficiency of the stove determines the resulting usable energy.
- Cropland is used for food production. Agricultural practices and food processing are conversion steps until the food is directly consumed or sold (for a discussion of human food chains, see Grupe 1991).
- The energy stored in pastures is made useful through livestock husbandry, which constitutes a central livelihood asset in the mountain communities. By grazing on the pastures, the animals collect biomass from large areas of grassland. Only a fraction of the energy content is usable by humans in the form of dried manure for heating purposes or in the form of dairy products and meat. Part of the dung and typically also side products from agriculture are returned as fertilizer on cropland and pastures. The importance of pastures and livestock for the livelihood of mountain populations is also reflected in the literature (Aknazarov 2003; Ludi 2003; Sedik 2009; Robinson et al 2010; Vanselow and Samimi 2011).

Figure 1 depicts the energy flow originating in primary biomass production. Additional energy inputs are always present in real systems and alter the energy balance. Also essential, but not specifically indicated in Figure 1, is human labor as an energy source necessary for basically all conversion steps.

Figure 1 shows the categorized conversion steps and thus the scope of action for how to influence the energy balance: Sustainable land management aims to avoid degradation of natural resources and conserve the productive potential of the land, and thus optimizes biomass generation (Hurni 1997). The efficiency of the different conversion steps can be influenced by good livestock management, appropriate agricultural techniques aimed at maximizing food production, and use of efficient stoves as well as improved thermal insulation, with the aim of minimizing thermal energy consumption.

The figure permits an understanding of land degradation as a symptom of degradation of ecosystem services, which itself is a result of an imbalance in the energy flow, whereby more energy is extracted from the ecosystem than is generated (Pimentel 1976). Not only does land degradation relate to the energy flow, but the state of development and human well-being in general as well. For example, climatic conditions have a twofold impact on energy flow. Cold temperatures and short vegetation periods found at high altitudes mean low primary production; that is, forest resources are scarce and agriculture is difficult. At the same time, long heating seasons increase the need for thermal energy, with higher demand and lower production. This might even lead to suppressed demand, which means that households are not able to meet their demand for thermal energy. Low production also has economic consequences: Since a considerable portion of food products cannot be produced but have to be bought, financial resources are

FIGURE 2 Location of the surveyed villages in the High Pamir and Pamir-Alai Mountains in Tajikistan and Kyrgyzstan. (Map by Philipp Koch, UNU-EHS)



tied to this purpose and not available for other investment. This highlights the crucial role energy plays in relation to not only land degradation but also development in general (see eg Romerio 2005).

Field study and methods

The energy flow through an ecosystem depends on the local conditions of a particular village. In a field study carried out in October 2009, the energy resources and consumption patterns in 5 villages were investigated. Figure 2 shows the geographical location of the villages, and Table 1 presents general information on the different villages. The case study villages were selected from each of the 3 major subregions: Shitkharv in the Western Pamirs, Bash Gumbez in the Eastern Pamirs, and Murdash in the Alai Mountains, so as to represent the diversity of the region. In addition, given notable ecological and cultural differences within the 3 major subregions, 2 additional villages, Kara Kabak and Oktaliok, were included in the study as representative of transitional zones between the Pamir-Alai region and the Eastern Pamir and between the Eastern and Western Pamirs, respectively.

In total, 26 semistructured household interviews, 5 group discussions, and several expert interviews and transect walks were conducted in the region. The core of the field survey was the interviews with households from different wealth groups selected by local partners (teachers, veterinarians, or representatives of village organizations). The interviews comprised collection of general data concerning the household (such as household structure, family members abroad, main occupations, income, land ownership, livestock numbers, pasture, and agricultural practices) and information on energy resources and energy consumption patterns (annual consumption of coal, firewood, dung—as both fuel and fertilizer—electrical appliances, expenses for energy, thermal insulation, heating period, and stove quality). This made it possible to establish a synthesis of the typical livelihoods, energy resources, and energy consumption patterns within a village. On the other hand, information on individual households provides insight into variations within a village and makes comparison between different household classes possible.

Of course, the small sample size limits drawing general conclusions, but it highlights the diversity of the region. Financial assets and wealth rankings are sensitive

TABLE 1 The 5 villages are located at different altitudes (indicated approximately) and have different climatic and geological conditions. The state of development and well-being correlates with the conditions for agriculture. The different ethnic groups (Kyrgyz and Pamiri) have different traditions—nomadic and settled—which influence both the land-use strategies and housing conditions. In the 2 states, land ownership and responsibilities for forests and communal land are regulated differently, and coal is regularly available only in Kyrgyzstan.

Features	Villages				
	Murdash	Kara Kabak	Bash Gumbez	Oktaliok	Shitkharv
Altitude (masl)	1800	3500	4000	3200	2800
Country	Kyrgyzstan	Kyrgyzstan	Tajikistan	Tajikistan	Tajikistan
Population	Kyrgyz	Kyrgyz	Kyrgyz	Pamiri	Pamiri
Households	644	117	138	17	104
Interviews	6	8	5	3	3
Electricity	Yes	Yes	No	Yes	Yes
Forest	Yes	No	No	Yes	Yes
Agriculture	Good	Difficult	No	Difficult	Good

information and highly complex issues. Within the context of this study, only partial and qualitative information was obtained, sufficient to establish 3 main wealth categories. All information from household interviews was confirmed and completed in group discussions and expert interviews and through field observations. The expert interviews were undertaken with employees of the local village administrations, teachers and veterinarians, representatives from nongovernmental organizations (NGOs) dealing with natural resource management and energy efficiency, namely, CAMP Alatoo, the Mountain Society Development Support Programme, and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ, now GIZ), and researchers from Osh University working on energy efficiency and forestry.

Village profiles

The information obtained in the study was used to compile village profiles, including land-use categories and energy resources, energy end use, and the flow of financial resources and energy. The village profiles represent some of the livelihood assets that are representative for a particular village. Figure 3 shows such a village profile. The solid arrows indicate the flow of energy or energy-containing material (see also Figure 1). The dotted arrows show financial flows. The dashed box indicates the local, coupled social-ecological system. Coal and electricity are external energy inputs, while remittances, salaries, and pensions, as well as access to external markets (implicit in the figure), constitute financial coupling to the outside world. The village profiles allow comparison of natural resources and livelihood assets between the villages.

Household diagrams

Complementing the village profiles, the household interviews make it possible to distinguish land-use strategies for different household categories within the same village. Household diagrams (Figures 4 and 5) were developed to provide key data on financial and natural assets as well as on energy consumption: number of livestock, money, land ownership, coal, firewood, and dung. The maximum value of the corresponding axis is indicated at the 6 outer points, and all axes start at zero. The interviews were qualitative, and the units concerned with energy consumption were local units of volume. The data collected were not precise enough to be meaningfully converted into standardized energy units. As mentioned before, information on financial assets was only partially and qualitatively obtained, such that no units are given on this axis. In addition, triangulation was sometimes difficult as some of the information was sensitive, for example, when collecting firewood is illegal. Therefore, a quantitative comparison of the surveyed households within the same village was possible only in approximate terms. For most aspects, only qualitative comparisons of general trends are meaningful between villages, in particular because of the different climatic and political conditions.

The diagrams distinguish between poor to average (green/gray lines) and average to rich (blue/dark lines) households. The wealth ranking was done by local partners and coincides with the information on livestock and monetary assets from the household interviews as well as with field observations. Data on all 6 factors were not always obtained for each household; hence the lines in Figures 4 and 5 are not systematically closed.

Results

As indicated in Table 1, endowment with natural resources is determined by location and climatic conditions and greatly influences the well-being of the villages. Field observations showed immediately that the conditions for agriculture and forest resources coincide with the livelihood assets in a village. As already discussed above, this reflects the fact that low biomass generation is combined with high demand for energy consumption, an

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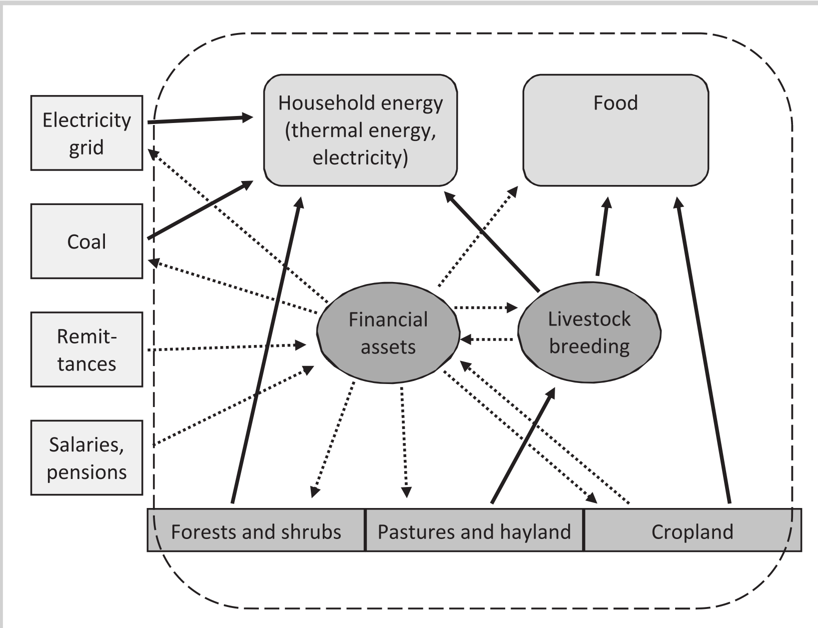
FIGURE 3 Example of a village profile. Bottom: land-use categories; top: main energy end uses. Financial assets and livestock breeding are 2 main livelihood assets that determine the well-being of a household in a particular village. The solid arrows indicate the flow of energy or energy containing material (compare with Figure 1). The dotted arrows show financial flows. The dashed box depicts the local coupled social-ecological system that interacts with the outside world through external energy inputs (coal and electricity) and financial means.



imbalance that affects development negatively. The harsher the environmental conditions, the less favorable the conditions for agriculture and the more important is livestock for household livelihood. At very high altitudes, few if any trees grow, and dung serves as a substitute for rather than a complement to firewood.

Maximum livestock numbers from the household interviews ranged from 5 livestock units at relatively low altitudes to 30 livestock units in high-altitude villages (Figures 4 and 5). Here 1 livestock unit is defined as 1 cow/yak/horse or 10 sheep/goats. In every village the livestock number is a wealth indicator.

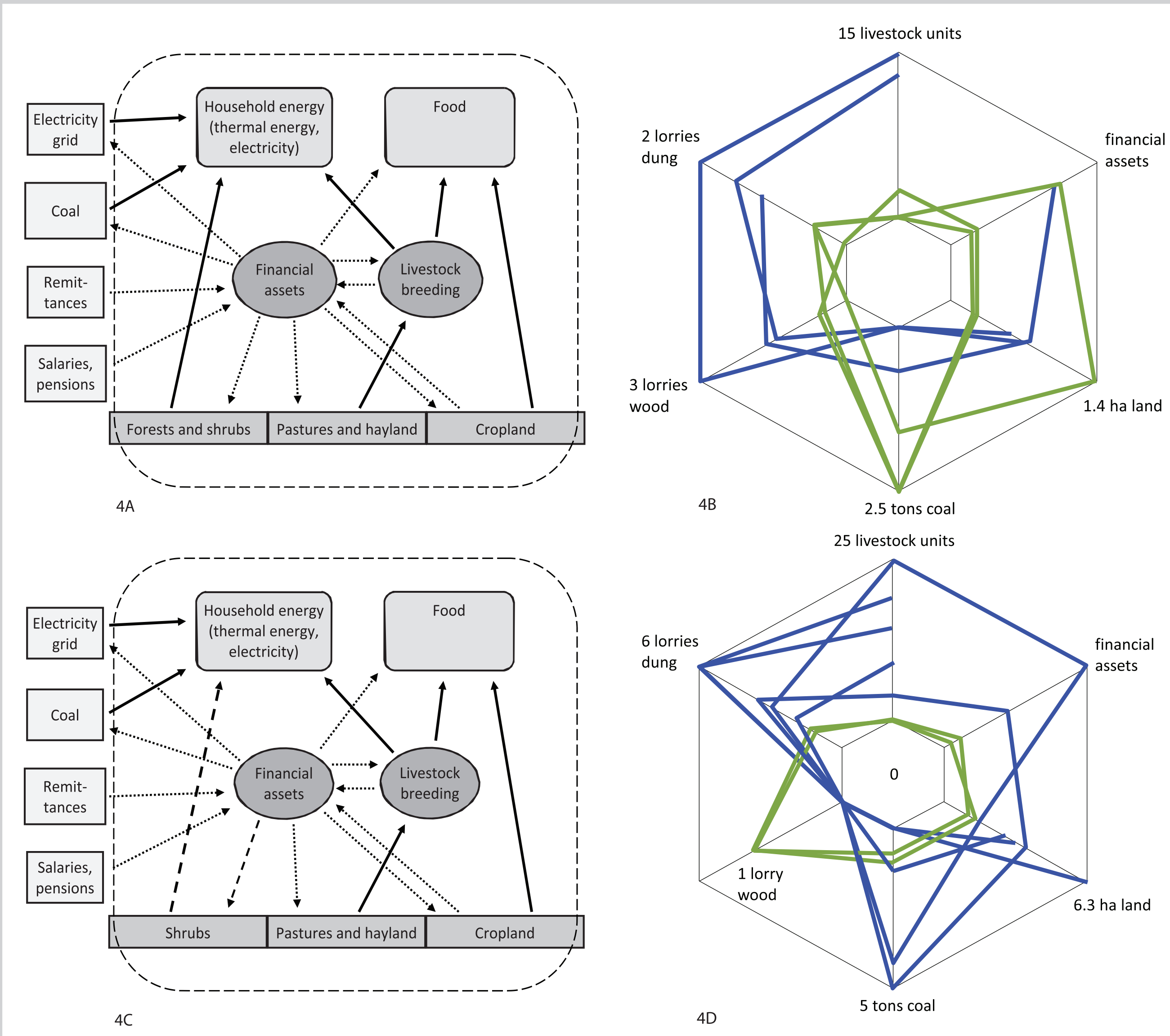
In addition to environmental conditions, political, institutional, and cultural aspects have a great influence on both development and energy issues. For example, in Tajikistan, none of our interview partners reported any use of coal since independence, while in Kyrgyzstan local coal mines are exploited, and, according to expert interviews, in 2009 villagers could buy coal at a subsidized prize. Also, management of pastures and responsibility for forests and communal land are regulated differently in the 2 countries, thus leading to different uses of the potential of land resources to generate primary energy.

Cultural aspects are also important but are not depicted in Figures 4 and 5. Both nomadic and settled lifestyles can be found in the Pamir-Alai Mountains and influence land-use strategies and food preferences. Kyrgyz people have a nomadic tradition and typically move with their animals to summer pastures for several months, which reduces the general pressure on the pastures and thus enhances the use of ecosystem services through mobility (for discussions on nomadic culture and ecosystems see Zhang et al 2007 and Kassam 2010). Field observations indicate that Kyrgyz communities often have an advanced pasture rotation system, whereas Pamiri villages often have more elaborate irrigation systems for agriculture than Kyrgyz villages. Another difference is observable in the housing conditions. While Kyrgyz houses are made of bricks and are of relatively simple design, Pamiri houses contain elaborate wooden structures and have identical divisions for all houses, regardless of the wealth of the family. The housing conditions strongly affect potential measures for increasing energy efficiency.

Household interviews showed that one strategy favored by the population to cope with high energy demand and scarce natural energy resources is to use coal as an additional input. Measures to promote energy efficiency, such as more efficient stoves or thermal insulation, do not seem to be considered by local people. According to expert interviews, this can be attributed to the fact that in the past, during the Soviet era, coal was provided, while energy efficiency is a relatively new idea in the region and sometimes requires alternative habits, which increases the obstacles to implementation.

Figures 4A and 4C show the village profiles for Murdash and Kara Kabak in Kyrgyzstan. In Murdash, agriculture is possible, and forests are present. During the summer, many families move with their animals for several months to summer pastures, where they also collect firewood for the winter. Households without livestock seem to have less dung available and draw upon nearby forest resources and/or are obliged to buy coal for heating.

FIGURE 4 Village profile and household diagram of Murdash (4A and 4B) and Kara Kabak (4C and 4D) in Kyrgyzstan (see text for more information). The annual consumption of firewood and dung is given in local units.

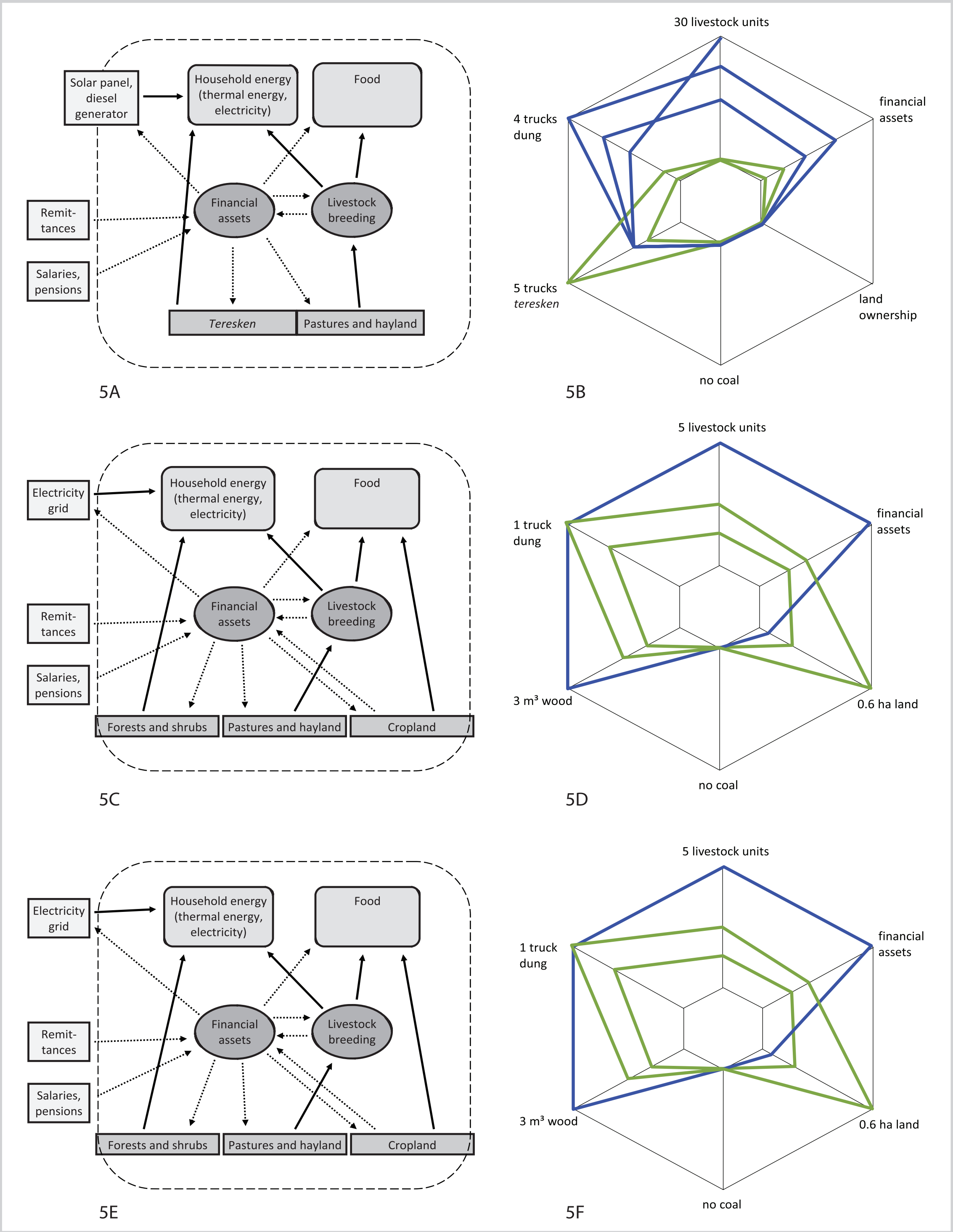


In Kara Kabak, no forests exist except for some shrubs along the river banks. Conditions for agriculture are harsh, and potatoes are the only crop grown, so that livestock breeding becomes very important. Rich households with many animals also have sufficient financial resources to buy coal, which was delivered (at the time of the field survey) at a subsidized price to both villages.

Comparing the household diagrams of Murdash and Kara Kabak (Figures 4B and 4D), clear differences in land use between rich and poor households become evident. In Murdash the surveyed households who own livestock and produce their own dung also have good access to firewood and better capacities to collect it, and they buy less coal than poorer households. In Kara Kabak, where the winters are much harsher and only some shrubs along the riverbanks grow, coal is far more important as a fuel than in Murdash. Rich households have sufficient financial assets to buy coal, while some very poor families rely partly on collecting driftwood and illegally cutting shrubs along the river, taking the risk of being fined. The land-use strategies of the poor and the rich interviewed in the 2 villages contrasted owing to different natural resources. It should be emphasized here that "poor" and "rich" are used as relative categories: A poor family in Murdash might have more livelihood assets than a poor family in Kara Kabak, which might also influence the choice of land-use strategies.

Figure 5 shows the village profiles and household diagrams of Bash Gumbez, Oktaliok, and Shitkharv. The 3 villages are located in Tajikistan, where no coal was available in the mountain villages at the time of the field survey.

FIGURE 5 Village profile and household diagram for Bash Gumbez (5A and 5B), Oktaliok (5C and 5D), and Shitkharv (5E and 5F) in Tajikistan (see text for more information). The annual consumption of firewood and dung is given in local units.



Bash Gumbez is located at an altitude of around 4000 m where no agriculture is possible and no trees grow (see Figure 5A). The village has no access to an electricity grid, but some households own small diesel generators and solar panels—typically the well-off families and the very poor, who benefit from solar panels distributed by an NGO. For fuelwood, people use *teresken* (*Ceratoides papposa*), a grass-like shrub with woody roots, which is well adapted to the harsh climate. In the last 20 years, a large area has been continuously cleared of *teresken*, such that people have to drive at least 20 km to collect it. The area cleared is prone to desertification. From the surveys, it is clear that a family without livestock needs more *teresken* than wealthier households, as it has reduced access to dung for heating (Figure 5B). Land ownership was reported in none of the interviews, which was attributed to the nonexistence of cropland.

Both Oktaliok and Shitkharv (Figures 5C and 5E) have forests and cropland. However, the climatic conditions for agriculture are much better in Shitkharv, which has led to better development of the village, confirmed during the household interviews and through field observations. Both villages have difficulties with electricity supply, particularly in winter, but in Shitkharv enough people have sufficient financial assets to invest in a local hydropower project. From the household diagrams (Figures 5D and 5F) it is apparent that the use of energy and thus the pressure on natural resources at the time of the study was related to household wealth: The wealthier a family, the more pressure it exerts on the forest ecosystems. The forests in Tajikistan are managed by a state agency, and people have to buy permits to collect firewood. New management arrangements are being introduced in order to reduce pressure on forestry resources by involving households directly in the maintenance of forests. This system has not yet been put in place in Shitkharv and Oktaliok.

Discussion and conclusion

In a global context, the potential of mountains for alternative, renewable energy resources and the strategies of mountain societies in the face of energy scarcity in harsh environments are highly relevant and can serve as informative examples. Our field survey highlights that energy is not just one service among many others provided by ecosystems but plays a crucial role in the life of mountain dwellers. Our results illustrate that the problems of poverty and land degradation are closely linked to energy and occurred at all observation sites. This confirms findings from earlier studies (Droux and Hoeck 2004; Hoeck et al 2007), and some of these links are also discussed in other contexts (Ellis-Jones 1999; Romerio 2005). In the Pamir-Alai region specifically, the collapse of the Soviet Union greatly altered the energy flow through the ecosystems, with respect to both agricultural practices and external energy supply, resulting in an imbalance of the energy flow, negatively impacting the well-being of the mountain societies and the mountain ecosystems. In addition, our approach and results highlight the correlation between environmental conditions, primary production, and the livelihood assets of the communities. Harsh climatic conditions imply a high energy demand but comparably little biomass production, for both agriculture and forestry resources. Typically this goes along with the remoteness of the villages and thus leads to considerably fewer livelihood assets.

Another general observation is that the awareness about energy issues is low. At the household level, energy provision is sometimes not seen as a problem, and its link to poverty and land degradation is not always acknowledged by communities. Inefficient stoves and poor thermal insulation are found in the homes without exception, and there is usually no awareness of measures to promote energy efficiency. Obviously, this impacts negatively on the scope of action of the local population. In addition, energy efficiency often requires initial investments for which many families lack the financial means, particularly considering that the benefits might not always pay back directly in cash. For a discussion of promoting alternative energy technologies, including efficiency measures in the mountain regions of Nepal, see Pokharel (2003).

Apart from the identification of some general issues and correlations occurring throughout all observation sites, our field study shows a great disparity between the situations of different villages. The interactions between political, environmental, climatic, social, cultural, and economic factors are complex and do not allow for easy prediction of particular manifestations of problems or specific solutions.

Our results show that depending on natural resources, the rich and the poor have different energy consumption patterns and different land-use strategies in different villages. By comparing the village profiles and the household diagrams of all 5 villages, a division in terms of energy resources and development that correlates with the conditions for agriculture becomes clear on a qualitative basis.

In villages at lower altitudes (in our case Murdash and Shitkharv), the natural resources and the livelihood assets of the village seem to be sufficient to allow the community to engage in improved and more sustainable land management as well as in measures that promote energy efficiency. For specific measures, see, for example, Liniger et al (2007). This can lead to a more sustainable use of energy resources in the future, if adequate incentives for sustainable use of forests and other locally available renewable energy resources are provided. Of course, also in villages that are comparably well off, very poor families exist that might need specific support in order to participate in the process of sustainable development.

In the other 3 villages at higher altitudes, both the available energy resources and the livelihood assets are not sufficient to improve the situation of households in any significant way. Here improved access to thermal energy and a subsidized supply for poor households, along with thermal insulation projects, will be required in order to improve livelihood conditions and to prevent desertification processes.

Many questions remain open, and this survey raises new issues. Future research should focus on how to communicate the importance of energy issues, and their link to land degradation and poverty, to the local population. The impact of political and organizational arrangements and cultural preferences on both natural resource management and energy consumption needs to be investigated, and good practices should be identified. To this end, a more detailed investigation of cultural and traditional aspects and attitudes concerning land management and energy use might be of great interest.

Concrete and specific measures for sustainable land management, energy efficiency, protection of ecosystems, and economic development need to be locally adapted and should be decided locally and in a participatory way.

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REFERENCES

Aknazarov KA. 2003. The present situation of pasture land in Eastern Pamir. *In:* Breckle S-W, editor. *Natur und Landnutzung im Pamir. Wie sind Erhalt der Biodiversität, Naturschutz und nachhaltige Landnutzung im Pamirgebirge in Einklang zu bringen?* Bielefelder Ökologische Beiträge 18. Bielefeld, Germany: Bielefeld University Press, pp 30–32.
Breu T, Hurni H. 2003. *The Tajik Pamirs: Challenges of Sustainable Development in an Isolated Mountain Region*. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, and Geographica Bernensia. http://www.north-south.unibe.ch/content.php/publication/id/1705; accessed on 22 September 2011.
Breu T, Hurni H, editors. 2005. *Baseline Survey on Sustainable Land Management in the Pamir-Alai Mountains: Synthesis Report*. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern.
Casimir MJ. 1991. Energieproduktion, Energieverbrauch und Energieflüsse in einer Talschaft des westlichen Himalayas. *In:* Herrmann B, editor. *Energie und Geschichte.* Saeculum Bd. 42(3/4). Cologne and Weimar, Germany: Böhlau Verlag, pp 246–260.
Droux R, Hoeck T. 2004. *Energy for Gorno Badakhshan: Hydropower and the Cultivation of Firewood* [Master's thesis]. Bern, Switzerland: University of Bern.
Ellis-Jones J. 1999. Poverty, land care, and sustainable livelihoods in hillside and mountain regions. *Mountain Research and Development* 19:179–190.
Grupe G. 1991. Das Management von Energieflüssen in menschlichen Nahrungsketten. *In:* Herrmann B, editor. *Energie und Geschichte.* Saeculum Bd. 42(3/4). Cologne and Weimar, Germany: Böhlau Verlag, pp 239–245.
Herbers H. 2003. Die postsowjetische Neuordnung der Landnutzung im Pamir: beeindruckender Erfolg mit kaum lösbaren Defiziten. *In:* Breckle S-W, editor. *Natur und Landnutzung im Pamir.* Bielefelder Ökologische Beiträge 18. Bielefeld, Germany: Bielefeld University Press, pp 88–97.
Hoeck T, Droux R, Breu T, Hurni H, Maselli D. 2007. Rural energy consumption and land degradation in a post-Soviet setting—an example from the west Pamir mountains in Tajikistan. *Energy for Sustainable Development* XI:48–57.
Hurni H. 1997. Concepts of sustainable land management. *ITC Journal* 3–4: 210–215. http://www.ces.iisc.ernet.in/energy/HC270799/LM/SUSLUP/KeySpeakers/AHurni.pdf; accessed on 22 September 2011.
IEA [International Energy Agency]. 2008. Country information for Kyrgyzstan and Tajikistan. http://www.iea.org/stats/index.asp; accessed on 4 April 2011.
Jedemann M. 2011. *The Impact of Decentralized Renewable Energy on Livelihoods: A Survey on Solar Home Systems for Villagers in the East Pamirs/Tajikistan* [Master's thesis]. Cologne, Germany: University of Cologne.
Kassam K-A S. 2010. Pluralism, resilience, and the ecology of survival: Case studies from the Pamir Mountains of Afghanistan. *Ecology and Society* 15(2): 1–19.
KZ [Kyrgyz Republic]. 2009. *The Kyrgyz Republic's Second National Communication to the United Nations Framework Convention on Climate Change*. Bishkek, Kyrgyzstan. http://unfccc.int/resource/docs/natc/kyrnc2e.pdf; accessed on 24 October 2011.
Liniger H, Critchley W, Gurtner M, Schwilch G, Mekdaschi Studer R, editors. 2007. *Where the Land Is Greener: Case Studies and Analysis of Soil and Water Conservation Initiatives Worldwide*. Bern, Switzerland: World Overview of Conservation Approaches and Technologies (WOCAT).
Ludi E. 2003. Sustainable pasture management in Kyrgyzstan and Tajikistan: Development needs and recommendations. *Mountain Research and Development* 23:119–123.
MEA [Millenium Ecosystem Assessment]. 2005. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.
Pimentel D, Terhune EC, Dyson-Hudson R, Rochereau S, Samis R, Smith EA, Denman D, Reifschneider D, Shepard M. 1976. Land degradation: Effects on food and energy resources. *Science* 8(194):149–155.
Pokharel S. 2003. Promotional issues on alternative energy technologies in Nepal. *Energy Policy* 31:307–318.
Robinson S, Safaraliev G, Muzofirshoev N. 2010. Carrying capacity of pasture and fodder resources in the Tajik Pamirs. FAO [Food and Agriculture Organization of the United Nations]. http://cashmereforum.files.wordpress.com/2010/06/carrying-capacity-of-pasture-and-fodder-resources-in-the-tajik-pamirs.pdf; accessed on 4 April 2011.
Romerio F. 2005. Energy, source of economic growth and development? *In:* Romerio F. *Risk Analysis in the Field of Energy Problems.* Rapport de Recherche du Centre universitaire d'étude des problèmes de l'énergie (CUEPE) No 6. Geneva, Switzerland: University of Geneva, pp 19–32. http://www.energie-cluster.ch/History/Bilder/NL_25/NL_2005_25_30_RapRech_Risk.pdf, accessed on 14 June 2011.
Schweizer P, Preiser K. 1997. Energy resources for remote highland areas. *In:* Messerli B, Ives J, editors. *Mountains of the World. A Global Priority*. New York, NY: Parthenon, pp 157–170.
Sedik D. 2009. The feed–livestock nexus in Tajikistan: Livestock development policy in Transition. FAO [Food and Agriculture Organization of the United Nations], *Policy Studies on Rural Transition* 2, 1. http://www.fao.org/fileadmin/user_upload/Europe/documents/Publications/Policy_Stdies/Livestock_en.pdf; accessed on 4 April 2011.
Shigaeva J, Kollmair M, Niederer P, Maselli D. 2007. Livelihoods in transition: Changing land use strategies and ecological implications in a post-Soviet setting (Kyrgyzstan), *Central Asian Survey* 26:389–406.
TJ [Republic of Tajikistan]. 2008. *The Second National Communication of the Republic of Tajikistan under the United Nations Framework Convention of Climate Change*. Dushanbe, Tajikistan. http://unfccc.int/resource/docs/natc/tainc2.pdf; accessed on 24 October 2011.
Vanselow K, Samimi C. 2011. GIS und statistische Modelle im Weidemanagement: Ein Beispiel anhand der Hochgebietsweiden im Ostpamir (Tadschikistan). *In:* Strobl J, Blaschke T, Griesebner G, editors. *Angewandte Geoinformatik 2011. Beiträge zum 23. AGIT Symposium Salzburg*. Salzburg, Austria: Wichmann, pp 625–634.
Zhang MA, Borjigin E, Zhang H. 2007. Mongolian nomadic culture and ecological culture: On the ecological reconstruction in the agro-pastoral mosaic zone in Northern China. *Ecological Economics* 62:19–26.
Zwölfer H. 1991. Das biologische Modell: Prinzipien des Energieflusses in Ökologischen Systemen. *In:* Herrmann B, editor. *Energie und Geschichte.* Saeculum Bd. 42(3/4). Cologne and Weimar, Germany: Böhlau Verlag, pp 225–238.

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