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Measuring Ecological Footprints of Subsistence Farmers in Ladakh

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ABSTRACT The paper presents a case study and a method to measure Ecological Footprints (EF) at sub-regional levels as indicators of environmental sustainability. Based on a three-month fieldwork study in the semi-arid mountainous desert of Ladakh, north India, the study attempts to calculate the Ecological Footprint of subsistence farmers of the Himalayas. The Ecological Footprint is used to compare the sustainability of two clusters of villages – one situated on the road, the other situated four days walk away from the road – and the ecological impact of their distinct paths of development. In Ladakh, the production system is highly integrated, and resources are scarce and used with a high degree of efficiency. Yet, the presence or absence of roads considerably influences the availability of resources, the options of development offered to people, and hence their Ecological Footprint. The study utilizes small-scale surveys and various proxies to adapt the component-based method to the physical and economic reality of Ladakh. Both for methodological reasons and analytical purposes, the Ecological Footprint is decomposed into different categories of soil, but also into local and imported footprints. EFs decomposed in such a way illustrate the impact of roads on two different types of development – one centralised and based on oil and imports, one decentralised and based on renewable energies and local resources. While evidence points to the loss of self-sufficiency in both regions, the paper further uses the Ecological Footprint method and empirical examples to suggest that biocapacity could be increased and self-sufficiency recaptured.

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The Ecological Footprint has the potential to bring a valuable contribution to the field of development studies. This is especially the case when it comes to defining and measuring the otherwise vaguely defined concept of "sustainable development". The Ecological Footprint is particularly useful in highlighting the global divide between the developed North, and the "underdeveloped" South, in terms of the consumption of ecological goods and services. By tracking down a country's resource consumption and waste production regardless of where in the world these are physically located, it can depict real patterns of unequal exchange, dependency and sustainability. The Ecological Footprint highlights inequalities in resource consumption worldwide, contextualized via characterizing the demands of humans on the biosphere with what is physically available on a planet bound by finite resources. It facilitates a questioning of the universality of a development model that cannot be generalised towards the rest of the planet. In this paper, the Ecological Footprint method is used to assess the draw on nature of subsistence farmers in Ladakh, a remote mountainous region in north India. It is also used as a tool to evaluate the sustainability of two different clusters of villages – one on the road, one four days walk away from the road – and two different kinds of development. This case study will therefore endeavour to contribute to the broader debate on Ecological Footprints and development[1].

This study presents multiple interests in terms of methodology and results. Firstly, the study offers the opportunity to calculate Ecological Footprints for sub-regional levels, in the context of a rural "subsistence" economy. It thus responds to the need expressed in the Africa 2006 Factbook "to further the debate at a more local level", though at a very different scale (Swiss Agency for Development and Cooperation & Global Footprint Network, 2006: p. 3). Secondly, the Ecological Footprint is used in this study as a comparative tool, and allows for an assessment of the environmental sustainability of two different paths of development: one based on imports and oil, the other one based on local resources and renewable energies. Thirdly, the relative proximity of the two populations studied here allows pointing to the factors responsible for discrepancies in Ecological Footprints, therefore understanding the conditions that could potentially lead to a sustainable development outcome. Finally, by studying the highly integrated agro-ecological system of subsistence farmers in Ladakh, it aims at widening our knowledge of "how much area does the human economy need to provide ecological goods and services" (Wackernagel et. Al, 2005: p. 27-28) for a specific kind of economic organisation.

Part one introduces the context of the study, and draws the general principles of Ladakh's agro-ecological system. This first step is important in order to understand the adaptations that had to be made to the standard Ecological Footprint method. Part two deals with the calculation methods used in this study. Part three presents and analyses the results. Part four concludes on the findings and their limitations, and discusses future scenarios for the region. It further opens the debates on the link between development and Footprints, and the dialectical relationship between human demand on nature and supply as captured by the Ecological Footprint method.

[1] This paper builds on a thesis submitted in partial fulfilment of the requirements for the Degree of Master in Philosophy in Development Studies (Demenge, 2005).

1. Context

1.1 Ladakh and its agro-ecological System

Ladakh is a mountainous region situated North of the Himalayas, and South of the Karakoram Range. Bordered by China in the east and Pakistani Kashmir in the west, it is the most northerly part of India. Ladakh's climate is referred to as a "cold desert" due to its combined features of arctic and desert climates. These include wide diurnal and seasonal fluctuations in temperature, from -40°C in winter to +35°C in summer, and extremely low precipitation, with an annual 10cm to 30cm primarily from snow (Ladakh Autonomous Hill Development Council, 2005). Due to high altitude and low humidity, the radiation level is amongst the highest in the world (up to 6-7 Kwh/mm). Finally, the soil is thin, sandy and porous. These combined factors explain why the entire area is nearly devoid of vegetation, with the exception of valley floors and irrigated areas.

Villages are situated at elevations of 2800m to 4100m above sea level. The economy of most villages in Ladakh is characterised by two elements: a high degree of self-sufficiency and internal recycling of energy and nutrients. Practices and institutions in Ladakh have evolved over centuries "by a process of constant refinement of response to the existing climatic and environmental conditions" (Rizvi, 1996: p. 173). All of life seems to be organised according a single principle: as Matthiessen (in Norberg-Hodge, 2000: p. xii) puts it "nothing is wasted and nothing thrown away; a use is found for everything".

In contrast to dominant systems of agriculture in the West, farming practices of the kind traditionally practiced in Ladakh place much emphasis upon internal recycling, self-sufficiency, and value complementarity and diversity extremely highly. In spite of harsh climatic conditions, Ladakhis have managed to develop a remarkably productive agricultural system, with yields often comparable to and even outcompeting those of European intensive regimes (Osmaston, 1994; Mankelow, 2003 and 2003b; LEDeG xxxx: p. 25; 27. See also table 5 in this paper). Yet, the availability of cultivable soil and, more critically, of water tend to limit both productivity of the land and areas that can be put under cultivation, and hence to some extent the size of villages. Droughts occur, forcing farmers to drastically reduce the area under cultivation, harvest earlier or plant in remote areas (Norber-Hodge, 2000: p. 11; Osmaston *et al.*, 1994: p. 6). Since the growing season is short (in most regions less than ninety days), fast-growing species of barley, wheat and peas are planted, and at lower altitudes one finds buckwheat, apricot and apple orchards[2].

[2] See LEDeG, xxxx: p. 27. Ladakhi families also cultivate a small kitchen garden that provides them with a wide variety of vegetables. However the most adapted species is, without doubt, barley: it grows at high altitudes and requires little water. Ladakhis use many different varieties of barley and exchange these every three years between villages to avoid exhausting the soil, limit propagation of pests and promote crossbreeding. Ladakhis also keep their land fragmented to reduce risks; work is organised communally, sharing labour and animals.

Livestock, mainly sheep, goats, yaks, cows, dzo[3], donkeys and horses, plays a central role, providing fuel, transport, labour, wool, milk, meat, hides and heat in winter. But most of all, animals allow the recycling of nutrients derived from agricultural wastes and pastures. With the exception of donkeys and horses, domesticated animals usually spend the summer grazing in high elevation pastures. Dung is collected from the pastures, fields and stables to be used as fuel and as fertilizer. Agricultural work is done with the help of animals, wind and water.

The Ladakhi subsistence economy is therefore an efficient system based on the exploitation of different and complementary agro-ecological zones: high elevation pastures, forests, and lower elevation irrigated agriculture fields (See figures 1 and 2). Although external resources are imported, the system is to a large extent self-sufficient, especially in remote valleys not yet connected to the road network.

However, it is difficult to understand Ladakh's rural economic system in isolation from the social system which it is a part of, and to understand the current situation without reference to recent trends and developments in the region (See Kaplanian, 1981; Norberg-Hodge, 2000). The critical issue for households depending on the land is to ensure a viable exploitation; this is made even more problematic when land and water are limited, and hence the size of cultivated land cannot easily be extended to meet the needs of the household. In Ladakh, rules of inheritance were such that households and estates passed in their entirety from generation to generation. Therefore, primogeniture was the rule. Furthermore, scarce resources limit the number of households that can make a living out the land. Thus polyandry and a high proportion of unmarried people were common[4]. In addition to leading to unity of the household, the system also tended to limit population growth.

The other central institution in Ladakh is the monastery. Monasteries still own vast lands that are cultivated by the village as a whole. Monasteries provide security to households in at least two ways. First, they provide extra land that can be put under cultivation when needed. Second, monasteries offer "'social security' for the whole community" (*Op. cit.* p. 79). Younger sons of large families with insufficient means would become monks. They would thus be provided for by the village in exchange for religious services.

The polyandrous and primogeniture-based system were outlawed by State legislations in the early 1940s, leading to a fragmentation of farming estates, and large estates owned by monasteries were dismantled[5]. Together, changes in the structure of the household, the weaker role of monasticism, as well as the health revolution have strongly contributed to demographic growth. From 1971 to 2001, the population of the

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[3] A *dzo* is a hybrid between the Yak and the cow. Ladakhis use different terms for the male, *dzo*, and the female, *dzo-mo*. Similarly, a *yak* designates the male, whereas the female is called *demo* or *dimo*. We will use the terms dzo and yak indifferently for males and females.

[4] Those latter either become monks or nuns, or stay in the village as unmarried individuals, helping with agricultural work. Although polyandry appears to be the favoured arrangement, it is by far not the only one. Monogamy is widespread, and polygamy (if for instance the first wife cannot bear children) is present as well. Daughters may also inherit land in some cases.

[5] See Norberg-Hodge 2000, p. 57. However, the effects seem mainly circumbscribed to areas close to administrative centers (Mankelow 2003).

district has increased from 51,891 to 117,637 inhabitants. This represents an average growth rate of 4.2 % per year, or + 126 percent in 30 years (Sources: LAHDC, 2005). This change is likely to have had implications on the consumption and availability of local resources.

Therefore, major changes to the socio-economic system have been taking place at a rapid pace over the last few decades. Other changes have been brought by the development of the infrastructure, and the availability of new working opportunities in government jobs, in the army who is very much present in the area, and more recently in tourism. In this context, the most important material change has been the opening of roads in the region, from the 1960s until now. Roads have allowed a new access to consumption and employment opportunities, driving villages away from their close dependency on the land and on locally available resources, for both production and consumption. The road also influences development opportunities available to villagers. For these reasons, the road is likely to have a palpable effect on villagers' Ecological Footprint.

1.2 Two Areas

The case study is based on the comparison of two clusters of villages. The first cluster is made of Alchi and Saspol, two villages situated on the Indus River. Both are situated on the road, three hours away by bus from the capital Leh, at an altitude of about 3150/3200 metres. The road which links Leh to Srinagar was opened in 1974, some thirty years before the study was conducted. The second cluster of villages is locally known as the *Trans-Singe La Region*, named after the 5000 m pass that separates the villages. It consists of the villages of Lingshed, Dibling[6], Skiumpata, Yulchang, Nierak and Photoksar; all are currently situated three to four days walk away from the road. Altitudes vary from 3700 m for the lowest (Nierak) to 4130 m for the highest (Photoksar).

The presence or absence of the road is the main factor that differentiates the region of Alchi-Saspol from the Trans-Singe La, as it facilitates movements of people, goods and agricultural inputs and outputs. The road allows people to commute as well as to import food, agricultural inputs, fuel and consumption goods. It also gives access to markets for vegetables, grain and wood, and allows tourists easy access to the village. The road is therefore expected to have a significant impact on the Ecological Footprint of the two villages.

As far as demographic trends are concerned, from 1981 to 2004 population growth has been more important in the Trans-Singe La region than in Alchi-Saspol: respectively + 57.6 % and + 45 % (Sources: Government of J&K, 2004; Statistics Department, Leh, 29.07.04 -unpublished)[7]. Migration is arguably taking place, as the weak rate of

[6] No research has been conducted there due to its remoteness from the other villages (more than a one day walk from Lingshed).

[7] However, when one looks at the evolution in the number of households, the tendency is inverse. The number of households has increased by 24 % in Alchi-Saspol, whereas it has remained relatively stable in the Trans-Singe La region with a marginal rise of 4 %. This points to the importance of social factors in

population growth tends to suggest, compared to that of the district (+ 71% over the same period). However both regions have been able to accommodate a larger population, independently of the existence of a road.

2. Method

2.1 General methodology

As defined in the literature, “Ecological Footprint accounts document how much of the annual regenerative capacity of the biosphere, expressed in mutually exclusive hectares of biologically productive land or sea area, is required to renew the resource throughput of a defined population in a given year—with the prevailing technology and resource management of that year” (Wackernagel *et. al.*, 2005: p. 4). Out of clarity and consistency with other Ecological Footprint studies, this paper uses the same terms and formulas as the relevant literature, and readers are invited to refer to the Global Footprint Network’s glossary for definition of technical terms (2006; see www.footprintstandards.org).

More recently, the Footprint Network has codified standards and stressed the need to stick to these standards. As stated in a more recent paper: “the value of the Footprint as a trusted sustainability metric therefore depends not only on the scientific integrity of the methodology, but also on consistent application of the methodology across analyses“ (Global Footprint Network 2005 Annual Report: p. 5). Although we acknowledge the utility of these standards and praise the initiative, it has to be noted that this study was conducted before these standards were available (June-August 2004). Moreover the availability and quality of data in Ladakh do not always allow strictly abiding by these standards, or make the use of alternative methods preferable[8]; the methodology may therefore appear unorthodox. However, efforts have been made to comply with these standards whenever this was possible, and it will be seen that the methodology used is no less rigorous or systematic. The following paragraphs sum up the modifications that were brought to the standard method(s).

The literature of reference tells us that there are two methods of calculating Ecological Footprints: the component-based approach, and when statistics are available, the compound method (Simmons, Lewis and Barrett 2000; Wackernagel et al. 2004, 2005). Our study uses both methods, and adds a third one. Figure 3 shows diagrammatically the three methods and their utilisation in order to process the different kinds of data available.

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explaining demographic changes, and the more complex relationship between the natural resource base and demographic trends (see Demenge 2005, 2006). Ecological scarcity and the absence of road probably play a role on demographic trends, but the results seem to indicate that the phenomenon happens at the level of households rather than at the level of the total population. Thus ecological scarcity and the absence of roads would limit the number of households that can draw their subsistence from local resources and livelihood options available, more than they limit the number of individuals. This issue is not dealt with in this paper.

[8] For instance, it was not possible to adopt the breakdown of consumption components for Footprint as advised in the standards (Food, Shelter, Mobility, Goods, Services). This will be explained in due course.

The compound method uses aggregate (national) data, and "captures the resource demand without having to know every single end use" (Wackernagel et al., 2005: p. 6). This method was used to calculate forests and carbon sequestration Footprints, using figures for consumption available through local authorities or through surveys. However, as the study deals with sub-regional level, figures for other resource uses were unavailable, or not quantifiable.

The component method "sums the Ecological Footprint of all relevant components of a population's resource consumption and waste production" (*Ibid.*: p. 5). In this paper, it is essentially used for imported products, either bought on the market or provided through the food distribution system, and which can be physically and reliably measured.

However, these two methods can only account for part of households' resource consumption and waste production, as most of the resources consumed by households are produced by households themselves. Moreover, even when it would be physically possible to measure the consumption of these resources or end-products, villagers use a loose system of measurement that varies from village to village, and many products such as dung (used mainly as fuel and manure) are not quantifiable. This makes any reliable figure difficult to obtain. Finally, the system is highly integrated, the same resources and waste products are used and reused at different stages of the production process, and the same land areas are utilised for different purposes. The use of both component and compound methods would be likely to lead to double counting, or at least to extremely complex calculations based on approximate estimations, and hence to inconsistent results. Therefore, it often makes more sense to track the use of resources at an early stage of production, rather than at the level of consumption, when it cannot be quantified anymore[9].

For these reasons, a third method was used to complement the two previous ones. The study deals with a population of subsistence farmers, who, using a certain surface of bioproductive land produce for their own consumption. This implies that the consumption of goods and use of resources can be tracked down directly from the land used to produce them to final consumption. To put it differently, the consumption of diverse primary, intermediary and end products is directly related to the land area used to produce them, and this area can be physically measured. This method was used for cropland, built-up land, and grazing land, although in this last case proxies had to be used (number and characteristics and feed requirements of grazing animals).

[9] For instance, cattle, horses, sheep, goats, donkeys and horses not only provide milk, meat, skins and wool (which are already difficult to quantify), but also transportation, labour for farming, heat in winter, and most importantly dung that is used for fertilizing the fields and as fuel for cooking and heating. Furthermore, out of the total livestock owned by the household, some will not survive the following year, and some are unproductive. Nevertheless all are necessary for the reproduction and functioning of the system. In this case, the figure for pastures can be approached through feed requirements for animals during the times they spend grazing. Trees are used for wood fuel, construction, insulation, fodder, fruit and oil (apricot). Crops and vegetable are not only consumed by the family, but are also bartered for other food, used for sowing, saved for bad years, and their waste constitute an important source of food for livestock. For these reasons, the method had to be adapted in order to deal with this complexity as accurately as possible.

Another deviation from the original method is that we differentiate a *local Footprint* and an *imported Footprint*, in order to account for the reality of subsistence households. The Local Footprint results from local land use for household consumption, whereas the Imported Footprint, results from the consumption of imported resources and energy, and from the creation of waste outside Ladakh. Together, they form the *Total Ecological Footprint*.

Both Footprints – local and imported – use the same categories of soil designated in the original method: (a) *cropland*, (b) *grazing land*, (c) *forests* (including *carbon sequestration areas*) and (d) *built-up land* (*Fisheries* have been omitted: they are irrelevant in the case of Ladakh as people do not consume any fish products)[10]. In both Footprints – Local and Imported – areas of soil are first expressed in hectares (ha) before being converted into global hectares (gha), by using their corresponding *yield factors* and *equivalence factors*. However, calculation methods, yields (and hence yield factors), as well as consequences in terms of energy consumption are different. Differentiating between the two Footprints simplifies the computation method. It is also useful for comparison between different Ecological Footprints, i.e. between the Footprints of the two regions in our case study, and for comparison with the biocapacity available per capita regionally, and worldwide.

2.2. Sources

Three types of sources of information have been used. The first and main source of information consists of data gathered through interviews, questionnaires, measurements and observations in the two regions studied: Alchi-Saspol, and the Trans-Singe La area[11]. Most of the data was obtained through a survey involving 41 households in Alchi-Saspol and 29 households in the Trans-Singe La region, representing a total of 179 and 180 individuals. The second source of information comes from official data: published documents, unpublished written documents and interviews with civil servants. The last sources and figures consist of specialised literature: on the Ecological Footprint, on the productivity of soils and of different ecosystems, and on energy consumption/requirements/contents, as well as pieces of advice from authorities in the fields of forestry, livestock husbandry and Ladakh.

2.3. Calculations

2.3.1. Local Footprint

a. Cropland

The local cropland area represents the area required to produce primary products (barley, wheat, peas, vegetables), and to provide for parts of feed for cattle (later translated into secondary products such as milk, butter, meat, hides, wool or dung). The size of the fields and gardens were given by interviewees in local units of measurements

[10] Nonetheless, fisheries have been included in the World biocapacity.
[11] Fieldwork was conducted in the region during June, July and August 2004.

(*kanal*[12] and *khal*[13]), translated into hectares through local (village specific) conversion factors, and added to give the cropland area. Data on items produced, consumed and sold by households were gathered too, in order to assess the actual households' cropland Footprint.

b. Grazing land

As explained previously, taking into account only animal products such as butter, meat and wool would have led to erroneous results. Other goods and services are also provided and most are not quantifiable. Furthermore, the household's livelihood depends on all the livestock, whether they do produce these final products or not. We therefore measured the total area used by the household for grazing their livestock. Nonetheless, shifting grazing is practiced and animals are left grazing over considerable areas of generally low but highly variable productivity. For this set of reasons, in order to measure the Ecological Footprint for grazing land we used the number of animals owned by each household. Energy requirements for each category of animal were deduced through average measures of weights, size and yields[14]. Energy requirements were then converted into areas of pasture using estimations of pasture yields[15], energy content of fodder and time of the year spent grazing (to simplify, it can be considered that animals generally spend the six winter months in stables fed on agricultural and food wastes and fodder, and six months grazing outside). This gave the grazing land Footprint[16].

Our calculations of Ecological Footprints for grazing land are independent from the fact that overgrazing might be taking place. Actually, evidence suggests that pastures are

[12] A *kanal* is an Indian measure of area. The standard conversion is 20 *kanal* per hectare.

[13] One *khal* equals half a *kanal* in Alchi and Saspol, and one third of a *kanal* in the Trans Singe-la area. A *khal* is not an "area measurement" but a "land measurement", the area being actually only one way among many others to designate the size of a plot of land. For a farmer in Ladakh, what matters is the quantity of seeds that have to be saved for sowing the next year. Hence a *khal* designates a fixed quantity of grain, or the land that can be sown with this quantity of grain. The number of *khal* depends on the size, as well as the quality, of the soil. Depending on the region, one *kanal* equals 1 to 3 *khal* (Osmaston and Rabgyas, 1994).

[14] Energy requirements per animal:

For yaks/demos, dzo/dzo-mo and cattle, the formula used is:

Summer energy requirement = 6/12 x [5000 (bodyweight x 33)] + 6 x milk yield in litres (from Osmaston 1994, p. 184; Buchanan-Smith 2001). Milk yields are negligible in winter. Average weights and milk yields from Osmaston 1994 and from data and observations during fieldwork.

For sheep and goats, the formula is: E= 0.8W + 10 in MJ per week. For a 15 kg sheep/goat, 22MJ a week, so 3.14 MJ a day, 573 MJ for a half year (deduced from Court and Seymour 2003).

For donkeys, the formula used is: 465 W0.75 KJ/day, so for a 100 kg donkey, 14.7 MJ/day, 5367 MJ/year, 2680 MJ from pastures if spending half year grazing (formula from Aganga, Letso and Aganga 2000). According to The Donkey Sanctuary (2005), the weight is around 100kg for average height at the withers of 90 cm, independently of heart girth.

Note that animals tend to be smaller in Ladakh than in most other regions. The average weights also account for the large proportion of young animals.

[15] Pasture yields were evaluated at 0.5-1 t/ha by Professor Bob Evans by analogy with Mongolia (personal communication). See also Wangdi (2002) on Bhutan, Pariyar (1998) on Nepal for similar figures. We chose the figure of 0.75 t/ha for pasture yields. Energy content: 6 MJ/t of grass at dry content (Osmaston, personal communication).

[16] Imprecision resulting from estimated productivity of pasture is compensated by the yield factor once converted into standardized global hectares.

submitted to heavy grazing pressure[17]. However, even though this diminishes the potential productivity of pastures, it also limits the total livestock that can be supported by pastures. Exceeding the present land's carrying capacity would rapidly lead to the regulation of livestock[18]. We can therefore reasonably assume that the quantity of livestock owned by each household corresponds to its Ecological Footprint for grazing land.

c. Forests

The local forest area was obtained by dividing wood consumption figures given by interviewees (mainly wood fuel) by estimated forest yields[19]. The task was complicated further in the case of the Trans-Singe La region, as inhabitants often had little notions of figures of wood in kilograms or quintals. People use yaks to carry the wood and consequently use yak loads to measure the quantities of wood they use. Figures in yak loads were converted into kg using reliable conversion factors given by informants on site and confirmed by the literature[20].

d. Built-up Land

The built-up land area measures the surface occupied by houses, stables and threshing areas. Because roads (when there are any roads) are generally built on non-productive land, these were not accounted for.

2.3.2. Imported Footprint

a. Cropland

The imported *cropland* area was calculated using average world yields given by the *Global Footprint Network's 2004 Edition* (GFN, 2004), and quantities of primary products consumed per household (bought on the market and through the Public Distribution System), as given by interviewees.

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[17] Osmaston, Frazer and Crook 1994.

[18] The quantity of livestock each household can possess is also limited by the labour requirement of every additional unit of livestock, particularly regarding foraging for winter fodder.

[19] Forest yields were estimated at 4-6 m^3/ha/year for populus nigra, salix alba and salix elegano, or 2-3 t/ha/year by Professors Jeffrey Burley and Peter Savill (personal communication). Here again, any imprecision due to estimation of yields is compensated for by the yield factor when converted into standardized hectare at world productivity.

Note: The figures of forest areas owned by households, as given by interviewees, were inconsistent with figures for wood use. They underestimate the real surface and are difficult to measure: trees are often planted in line along the canals and along the fields, or trees and shrubs are mixed with grazing lands and gardens.

[20] See Wiener, Jianlin and Ruijun (2003). A yak load is about 80 kg. Although a yak can carry more over short distances, wood collection is often done in remote valleys separated by high passes. Such a figure accounts for the size of the bulk, which in such conditions is limited.

Note that Ladakh's forests are used for wood fuel, construction and fodder. Therefore forests are not available for carbon sequestration. Carbon sequestration land is therefore accounted for in the *Imported Footprint*

b. Grazing land

Imported grazing land areas were computed using the quantities of imported secondary products bought by households and *World conversion factors* (*Ibid.*). For meat products[21], the amount of meat consumed was multiplied by the *feed conversion efficiency factor* (that is the amount of pasture or energy required to produce one kilo of secondary product) and by the *live weight factor* (which converts product weight – in tonnes of meat - to live weight equivalent). This gave the Footprint per ton of product. Results were directly obtained in global hectares[22].

c. Forests

The imported forest Footprint was obtained by multiplying imported quantities of wood by world yields (*Ibid.*).

d. Built-up land

We did not account for any imported built-up land: data was not available, and quantities are likely to be negligible.

e. CO2 area

The CO2 area, or energy area, represents the area necessary to assimilate carbon dioxide emissions resulting from the combustion of fossil fuels used by households, directly, or indirectly through consumption[23]. The Energy consumption consists of different categories:

- Fossil fuels consumed by households. The figures on quantities of kerosene oil, petrol, diesel and on the number of gas cylinders used were collected through survey.
- Diesel consumed by the village for electricity generation[24].
- *Embodied energy in trade*[25] for imported food and consumption goods.
- *Transport penalty*, which accounts for the quantity of diesel necessary to ship a certain weight of goods, oil and gas to Ladakh. Importing goods to Ladakh necessitates the shipping of goods by truck across the Himalayas with passes as high as 5300 m

[21] Ladakhis, like Tibetan, eat small quantities of meat even though they are Buddhist. Most of the meat is consumed during *Losar* (new year), and in winter.

[22] Quantities of butter imported were multiplied by 20 in order to obtain the quantity of milk consumed. This is a compromise between the share of the milk effectively consumed, and the quantity of milk necessary to make butter (the fat content is normally lower than 5%).

[23] Although Ladakh does produce some electricity through hydropower, none of the areas studied here gets its electricity from this source. Primary energy consumption results entirely from fossil fuels, wood, and solar power. Wood consumption is already taken into account in local forest areas, and photovoltaic and other solar devices do not produce any Footprint as they use solar radiations and are placed on the roof of habitations.

[24] Data from the Power Development Department, Leh, 27.08.04.

[25] Global Footprint Network (2004). The embodied energy in trade accounts for the fact that primary and secondary products imported embody a certain quantity of energy. This was taken into account and translated into carbon emissions (we used the world national carbon intensity index). The method was then the same as for carbon sequestration, to obtain an energy Footprint (in gha).

(covering the distance one way takes about three days by truck). It is therefore an energy intensive process, which we accounted for in our calculations.[26]

Once the total quantities of kerosene, petrol, diesel and gas directly and indirectly consumed were calculated[27], those were converted into quantities of carbon[28] emitted using *carbon intensity factors* for gas and fuel (Global Footprint Network, 2004). Carbon dioxide emissions resulting from fossil fuels burning are mainly absorbed by the oceans and by forests. Citing the IPCC, the Global Footprint Network (*Ibid.*) notes that out of the total CO2 emissions, 29 % are absorbed by the oceans. The rest of the carbon contained in CO2 emissions (each tonne of CO2 contains 0.273 tonnes of carbon) is sequestrated by forests. *Terrestrial Sequestration* (on forested areas) is deduced from world average *forest yields* and the average *content of carbon* in a tonne of dry matter: 1 tonne of carbon per hectare per year. Converted into gha (through the *Energy Land Equivalence Factor*, this means that the sequestration of one tonne of carbon emitted and not absorbed by the oceans necessitates an area of 1.38 gha. In other words, for each tonne of carbon emitted, 290 kg of carbon are absorbed by oceans, and the remaining 710 kg are absorbed by an area of 0.980 gha (1.38 X 0.71 = 0.980).

2.3.3. Total Ecological Footprint

Yield factors and Equivalence factors

Each area was then divided by the number of people represented in the sample, or by the number of inhabitants in the village when the data was given at the scale of the village. Hence, areas are expressed on a per capita basis.

Footprints of each category (in ha) were converted into standardized hectares (in gha) using the corresponding yield factor and equivalence factor (see table 4). Equivalence factors were given by the Global Footprint Network (2004). Regarding yield factors for

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[26] Each truck carrying goods and fuel to Ladakh consumes an average 500 L of diesel to cover the distance Leh-Manali, or Leh-Srinagar and back (result of a small survey done with truck drivers in Leh). Each truck is limited to a load of 60 quintals of goods, 9000 L of oil, or 10000 L of diesel (average: 9500 L; figures from the Excise and Taxation office, Leh, 30.07.04). We therefore applied a transport penalty on every kilo of goods or litre of fossil fuel imported by truck to Ladakh. The amount of the penalty is:
- 500/60 = 8.3 L/qtl of imported goods.
- 500/9500 = 0.053 L/L; i.e. we add a penalty of 5.3 % on ever litre of fuel imported into Ladakh.

The figures on truck consumption obtained through a limited survey in Leh (six truck drivers) are also compatible with those that can be found in the literature. According to a test made on a sample of 25 Tata trucks from 1 to 15 years old, the average consumption was 27.54 L/100 km: "an Index of Performance which takes into account the load factor and route difficulty of their trucks." (Rao, P C and T C Pearce 1996). Nonetheless, according to Volvo Trucks India (2005): "One additional stop every 10 km increases the fuel consumption by approximately 35%. 10 stops and accelerations per 10 km increase fuel consumption by 130%", "constant up and downhill driving or city driving with many stops may increase fuel consumption by more than 50%". Therefore, a consumption around 50 L/100 km seems perfectly plausible on the Trans-Himalayan highway, a road on which two trucks can barely pass each other and have to cross passes at 5,100 and 5,300m.

[27] For diesel, kerosene and petrol, figures for gross calorific value were deduced from DEFRA (2000) (Initial formulas for gross calorific values in kWh/L). For Gas (LPG), gas content (butane-propane), quantity of gas and calorific values were calculated using Indian Oil Company (2005) http://www.ioclebiz.com/lpg/stc_lpg_faqs.asp, and Comité Français du Butane et du Propane (2005).

[28] Weights of CO2 and carbon have been clearly distinguished in the calculations.

imported Footprints, those are always equal to 1 as imported Footprints were measured at average world productivity for each item. Regarding yield factors for local Footprints, those were deduced from measured and estimated yields for each category of soil (see table 4 and figure 5).

Checking procedures

We have used checking procedures in order to minimise errors and imprecision due to estimations and misreporting. Figures and formulas from Global Footprint Network are already submitted to rigorous tests of validity, and as such were accepted as valid. Other formulas and figures were obtained from reliable sources and compared one against the other. The methods chosen to compute Footprints were rigorously selected, whereas more imprecise formulas or those giving unlikely results where dismissed. In addition, the following tests have been performed:

- Comparison with quotas from the Public Distribution System: the data obtained was compared with the data of food distribution obtained from the Department of Consumers Affairs & Public Distribution[29], and with quotas for food and kerosene distribution per capita[30].
- Energy available from food consumption: the data for food consumption was tested against daily energy needs to assess its validity.

2.3.4. Biocapacity

The Ecological Footprints obtained have been compared to three different types of biocapacity: an estimation of the *actual local* (or *regional*) *biocapacity* at the district level, the *potential biocapacity* at the district level (which is used to assess future scenarios for the region), and the *World biocapacity*. Whereas Ecological Footprints were calculated at the village level, an estimation of the actual local biocapacity available per capita was calculated at the district level. Figures to calculate biocapacity at the village level often did not exist. And when they did exist, their validity was sometimes questionable[31]. Furthermore, we had no data for forests or grazing land areas.

a. Actual local biocapacity at the district level

An estimation of the actual local biocapacity was obtained by the addition of the four categories of soil – (a) cropland area, (b) grazing land area, (c) forest area, and (d) built-up area each multiplied by their corresponding yield factor, and finally by their individual equivalence factor in order to obtain standardized measures in gha.

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[29] Leh, 27.08.04.

[30] Op cit.

[31] Figures for land use from the *Village Amenity Directory* (2002-2003) date from the 1981 census, and therefore were not up-to-date. For Alchi and Saspol, the total sown area divided by population gave a cropland area of 0.09 ha/cap, whereas our inquiry reported an area of at least 0.14 ha/cap. If data for the sown area in 1981 was accurate, then the area brought under cultivation has expanded by the corresponding amount since.

For cropland (a) and built-up land (d), figures from the Government of Jammu and Kashmir 2004 Statistics were used (J&K 2004). For forests (d), figures provided by the Forest Survey of India 2004 were used[32]. For grazing land (c) the following method was used: the official figure of 1,092 hectares of pasture for Ladakh would have given a biocapacity per capita of 0.01 ha/cap, which is far below the per capita requirement, and incompatible with the number of grazing animals. We therefore used the same technique as in the calculation of the local grazing land Footprint, using the data on livestock in Ladakh (J&K, 2004), and supposing that pastures were used at their present optimal capacity. Yet, because of that, the figure obtained here corresponds more to an estimation of the actual local biocapacity based on land use at the district level, and conclusions on sustainability based on this figure have to be handled cautiously.

b. Potential biocapacity at the district level

The potential biocapacity accounts for the biocapacity of Ladakh if agriculture was extended to 1% of the territory, as is theoretically possible[33]. We took the same figures for pasture, forests and built-up land as in the actual biocapacity, but replaced the sown area by the potentially cultivable area, i.e. 1 % of the district area, all other things being equal. This scenario is valid under the assumption that the productivity for cropland remains unchanged, and that the new cropland does not replace land previously affected to other categories of land use or that land used for forests and pastures is displaced to land of at least equal yields.

c. World biocapacity

Finally, we used the figure for World biocapacity provided in Global Footprint Network 2004.

3. Results

3.1. Analysis of Ecological Footprints

The results are far from being self-evident, and allow us identifying interesting patterns (see tables 6 and 7). Overall, Ecological Footprints for both Alchi-Saspol and the Trans-Singe La region are relatively small compared to the world average Ecological Footprint: respectively 1.12 gha/cap and 0.69 gha/cap, compared to 2.2 gha/cap for the world average Ecological Footprint (European Environmental Agency and Global Footprint Network, 2005). Having said that, they are however larger than we would

[32] Forest Survey of India (2004), Ministry of Environment and Forests, Government of India. http://www.fsiorg.net/fsi2003/states/index.asp?state_code=11&district_code=200. Figures obtained by adding data from J&K 2004 for forest, trees, departmental nurseries, departmental plantations and community plantations were not compatible with the actual wood consumption, and high interannual variations are evidences of misreporting.

[33] 1 % of the territory is an upper limit, supposing that water supplies can be successfully harnessed. Presently, only ¼ % of the territory is cultivated (Osmaston 1989, p. 130). The Agriculture department documents land uses for a reporting area of 51,269 ha, that is 1.14 % of the territory. The total area sown is 10,478 ha, which represents 0.23 % of the district area (45,110 km2 if one exclude the 37,555 km2 under Chinese occupation; Source: Government of J&K 2004).

have expected given consumption patterns and the constant emphasis on recycling of nutriments. It may be a feature of self-sufficient systems, in which the utility of elements is assessed relatively to a variety of functions and performances rather than to one specific one, and stability of yields is valued over productivity[34]. Compared to a specialised system, a self-sufficient system may therefore lead to higher Ecological Footprints, for a similar output.

Interesting conclusions can be drawn out of the internal structure of Ecological Footprints (See tables 6 and 7, and figure 8). Let us start with the imported Footprint. The results broadly conform to our expectations. Alchi-Saspol's imported Footprint is relatively important (0.55 gha/cap) compared to its local Footprint (0.58 gha/cap) although its inhabitants still heavily depend on local resources. It is interesting to note that a substantial part of the imported Footprint consists of the energy Footprint (0.33 gha/cap). By opposition, the Trans-Singe La's imported Footprint is extremely small (0.05 gha/cap).

Regarding the local Footprint, it is larger for the Trans-Sing La region: 0.63 gha/cap compared to 0.58 gha/cap for Alchi-Saspol, documenting the higher reliance on local resources. Yet, although the Trans-Singe La depends more heavily on local resources, its local cropland Footprint (0.21 gha/cap) is also smaller than that of Alchi (0.30 gha/cap). This could suggest a lower consumption, but also a better or more intensive use of soils, and a better productivity of soils[35]. As for the Footprint for grazing-land, it is significantly bigger in the Trans-Singe La region (0.34 gha) than in Alchi-Saspol (0.22 gha): this points to the fundamental role of livestock in the economy of the Trans-Singe La, as animal power, transport, fuel and source of manure[36].

The energy Footprints deserve special attention too. As it has been previously mentioned it is a lot larger in Alchi-Saspol (0.33 gha) than in the Trans-Singe La region (0.01 gha). Actually, for the latter much of the energy used is derived from grazing lands, crop waste and forests (through dung and woodfire), and thus is not counted here as energy Footprint. Furthermore people in the region get their electricity from photovoltaics and intensively use solar cookers and water heaters, counted here as built land. By opposition, inhabitants of Alchi-Saspol import gas cylinders, get electricity from a diesel generator, and use more mechanised transports. Together, the results suggest the existence of two distinct patterns of use of land and energy.

3.2. Biocapacity and sustainability

As stated earlier, three types of measures of biocapacity are used in this paper: an estimation of the actual local biocapacity at the region's level, the World biocapacity, and a potential biocapacity.

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[34] For instance yaks, dzo and cows may produce little or no milk, they are however kept for the variety of other functions they perform. More animals than necessary are also kept to make up for higher mortality rates of animals during winter.

[35] This could also be explained by trade, but trade is limited, it mainly concerns vegetables, and this was subtracted from Ecological Footprint measures.

[36] This centrality of livestock, and especially yaks, in the economy of the region has led us to call it elsewhere "the economy of the yak" (see Demenge, 2005).

With regards to actual local (or regional) biocapacity (see figure 9), it should be noted that in both regions the use of natural resources as measured by the local Footprint appears to be superior to the biocapacity regionally available in Ladakh, as per our estimations. The results, which are compiled in table 9, suggest that the use of local renewable resources reaches a physical limit: the limit of the biocapacity of the land regionally available. This makes it impossible to satisfy needs locally; hence all additional consumption of resources must be provided for by importing biocapacity[37].

The need to import biocapacity is made clearer when the total Ecological Footprint is compared to our estimation of the regional biocapacity. The figures of ecological deficits (table 10 and 11; see also figure 12) point to the impossibility of satisfying needs locally, with immediately available resources. For the Trans-Singe La region, the total ecological deficit is –0.12 gha/cap; for Alchi-Saspol, the ecological deficit amounts to –0.56 gha/cap (see table 11). This results in a dependence of both areas on imported biocapacity, although this dependence differs in magnitude.

As far as the World biocapacity is concerned, Alchi/Saspol's and the Trans-Singe La's Ecological Footprints are well below it (1.8 gha/cap). Thus according to our results, both Alchi-Saspol and the Trans-Sing La display ecological surpluses of 0.70 and 1.13 gha/cap[38].

In terms of sustainability, the conclusion differs depending on which criterion is chosen: regional biocapacity or World biocapacity. In the first case both regions are ecologically unsustainable, as the Ecological Footprints of both regions are larger than the regional biocapacity available per capita. This implies either an import of biocapacity or a reduced access to the natural resource base for other villages, if the long-term productivity of the regional ecosystem is not to be endangered. In the second case, that is using World biocapacity as the criterion, both regions are sustainable as the use of biocapacity does not threaten long-term productivity of the biosphere.

3.3. Potential biocapacity: a scenario for future

A third kind of biocapacity is considered – the potential biocapacity – based on a potential scenario for Ladakh. It accounts for the biocapacity of Ladakh if agriculture were extended to 1% of the territory, as is theoretically possible[39]. This would result in a

[37] Note that our methods of calculation for local biocapacity makes the argument quite tautological: since people import resources we deduce that the Ecological Footprint is bigger than the local biocapacity; and because the local Ecological Footprint is bigger than the local biocapacity people have to import resources. We are aware of this shortcoming, which can unfortunately hardly be overcome given the availability of existing regional data. This problem does not exist when using the world biocapacity.

[38] Note that Ecological Footprints could also have been compared to the Indian biocapacity, as given by the Footprint Network: 0.4 gha/cap. This would give ecological deficits of -0.7 for Alchi-Saspol and -0.3 gha/cap for the Trans-Singe La region. This further brings the question of whether it is desirable for Ladakh to remain ecologically dependent on the rest of the country, which already runs an ecological deficit of -0.4 gha/cap.

[39] 1 % of the territory is an upper limit, supposing that water supplies can be successfully harnessed. Presently, only ¼ % of the territory is cultivated (Osmaston, 1989: p. 130). The Agriculture department

regional biocapacity of 1.21 gha/cap, which would be largely sufficient for Ladakhi needs (See table 9 and figure 12). In that hypothetical situation, both Alchi/Saspol's and the Trans Singe-La region's Ecological Footprints could be inferior to the local biocapacity. Increasing the cropland area would not be the only mean: any increase of productivity, or better use of locally available resources (such as solar energy, which could result in more manure and nitrogen being made available for fertilizing croplands) could be part of the solution[40]. Any increase in local biocapacity would also lead to a decrease in imports, and therefore in lower imported Footprints, all other things being equal[41]. This in turn is extremely likely to result in smaller Ecological Footprints, in so far as the individual Footprint of locally produced goods is normally significantly lower than that of imported goods (which includes energy for production and transport). Any step in this direction would contribute to recapturing the regions' sustainability.

This discussion attempts to bring a balanced response to the question of biocapacity and the widest sustainability debate regarding the two regions studied here, considering the data presently available. Hence conclusions differ depending upon which biocapacity the Ecological Footprint is compared to: regional or World biocapacity. Moreover, keeping in mind that measures of Ecological Footprints and biocapacity represent the consumption and availability of renewable resources at a certain moment in time, it is possible to draw a future scenario under which the ecological sustainability and self-sufficiency of both regions could potentially be recaptured. This will be discussed further in our conclusions.

4. Conclusions

In this paper, we have tried to show that in order to compute the Ecological Footprint of Ladakhi subsistence farmers, specific arrangements to the original method had to be made. The method used was not the only one that could be used, and improvements could be made to lead to more accurate, complete and detailed results. Methodological issues due to the lack of existing data were exposed, particularly regarding the regional biocapacity. This issue could be overcome through land mapping and precise measurements of productivity of soils. The study might also benefit from a better sampling of households and systematic measurements of quantities consumed by

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documents land uses for a reporting area of 51,269 ha, that is 1.14 % of the territory. The total area sown is 10,478 ha, which represents 0.23 % of the district area (45,110 km2 if one excludes the 37,555 km2 under Chinese occupation; Source: Government of J&K 2004).

This would necessitate harnessing irrigation potential, lifting water, and putting new land under cultivation. Lifting water can be done using solar pumps and ram pumps. This would represent an investment, but this is not unrealistic if agriculture was rendered profitable through the lifting of subsidies on imported food which depress local prices.

[40] See Osmaston, 1994b. There are several plans to increase the availability of manure for the fields through well functioning techniques: generalisation of the dry latrines system, composting or vermicompost to cite only a few of them (LAHDC, 2005b; Cooperative department, Leh, 30.07.04; Agriculture department, Leh, 05.08.04; Zubir Ahmad, Chuchot, 17.07.04).

[41] This is true in so far as it does not result in an increased consumption of other imported goods. Note that all other things being equal, an increase in productivity does lead to a decrease in the land area effectively used (in ha), but does not lead to a decrease of the local Footprint (gha). This is due to the change in the *yield factor*, which converts local hectares into global hectares at world productivity (see chapter 4).

households over a full year. Yet, it is not certain how such a time and resource intensive process might lead to significant improvements in the results. However, the method has enabled us to highlight the fundamental trends and differences that differentiate the two cases. Leaving aside methodological considerations, five practical and theoretical conclusions can be drawn out of this case study.

Firstly, the case study allows us to identify two patterns of use of land and resources. These are clearly highlighted by the Ecological Footprints, and more especially by their internal structure. Interestingly, one cluster of villages (Alchi-Saspol) is highly dependent on imports, whereas the other is not. The Trans-Singe La remains to a large extent based on the exploitation of local and immediately available resources.

Secondly, conclusions based on Ecological Footprints allow us identifying two modes of development. The case of the Trans-Singe La is characterised by a more intensive use of local resources and a higher degree of self-sufficiency[42]. Hence, livestock has retained its centrality in the system, providing different products, transport and animal power, and more fundamentally manure, enabling farmers to exploit the productivity of pastures and recycle nutriments to intensify and extensify agriculture. Moreover, villagers have made a more intensive use of new technologies and locally available sources of energy, mainly solar, using photovoltaics, solar cookers and water heaters, greenhouses and solar buildings. These features have allowed the villagers to maintain an Ecological Footprint close the local biocapacity. By opposition Alchi-Saspol's economy is widely based on external employment and imports (food, wood, cement). Importantly, its villagers own less livestock, which means fewer transportation means and labour power, and they get less manure to fertilise the fields. Consequently they rely more heavily on imports: oil, gas, kerosene, chemical fertilizers, and food. The comparison between two similar regions and their two very distinct paths of development contributes to the debate over Ecological Footprints and development. It shows that socio-economic development may not inevitably lead to higher Ecological Footprints, or that if an increase occurs, its magnitude may vary widely from one situation to the other.

Thirdly, it is interesting to observe that areas with similar conditions and initial endowment in resources (although Alchi-Saspol is slightly better off due to its lower altitude) may follow very different paths of development, leading to such different outcomes. Yet as it has been previously stated, the presence or absence of a road is the factor that differentiates the two clusters of villages. It is also at the centre of Alchi-Saspol's livelihood strategies and economic system, and to a large extent the effects of the road can be measured in the region's Ecological Footprint. In Alchi-Saspol, the road has enabled its villagers to depend on imports of external resources, including oil. In the Trans-Singe La the absence of road has compelled the inhabitants into ecological development. The isolation of the region has pushed the population (with the help of the local government and NGOs) into harnessing the energies and resources locally available[43]. The presence or absence of roads therefore becomes the main factor

[42] For instance in the Trans-Singe La 75% of the food consumed is produced by households, against 58% for Alchi-Saspol.
[43] In the field of appropriate and clean technologies, a huge and successful effort has been made to harness Ladakh's largest potential: hydraulic energy, but most of all an average of 325 days of sunshine a

responsible for the different paths of development followed, leading to different degrees of ecological sustainability[44].

Fourthly, when put side by side with figures of demographic changes, measures of Ecological Footprints in the two regions may lead to questioning the relationship between limited resources, biocapacity and population growth. Interestingly, the increase in population has been larger in the Trans-Singe La (+57.6% from 1981 to 2004), region in which the possibilities to import resources are much more limited, than in Alchi-Saspol (+45%). Over the same period, the cultivated area has increased. Although historical data would be useful to prove what follows, it is actually likely that the natural resource base has increased with human population's needs. This does not mean that the limit of the biocapacity is indefinitely expandable, especially in a place like Ladakh in which resources are present in limited supply. Yet, under certain conditions, it is possible that population growth and increasing human needs may lead to a better management of natural resources, agricultural extensification and intensification, and therefore to an increase in the total biologically productive area in the region. It has to be stressed that in Ladakh, the biocapacity is largely "created" by farmers: by irrigating, fertilizing and creating new fields out of barren land, and by planting forests in valley floors. This would link this case-study to a wide array of literature that shows that population growth can lead to an increase in- and a better management of the resource base (Boserup, 1965; Tiffen *et al.*, 1994; Fairhead and Leach, 1996). This would also give weight to our Potential scenario, showing that would the circumstances arise and political will happen, the self-sufficiency and ecological sustainability of the region could potentially be recaptured.

Finally, it might be interesting at this stage to reflect on the capacity of Ecological Footprints to adequately represent and theorise the relationship between human populations and the resource base, and hence the Footprint's ability to be used as an indicator of ecological sustainability. The Ecological Footprint teaches us that the biocapacity, which may vary in time, influences the amount of population that can live in an environment, and/or their level of resources consumption. It also teaches us that too high an Ecological Footprint may result in eroding the natural capital, diminishing year after year its capacity to regenerate and lowering the biocapacity available for human appropriation, and therefore human's future Ecological Footprint. Through the Ecological Footprint method, this case study suggests that the biocapacity is also to a large extent the product of human activities, and that Ladakhi farmers may create and

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year with solar radiation among the highest in the world. This unique situation offers the potential for energy production based on renewable energies. Technologies include photovoltaics (PV), solar space heating techniques, solar water heaters, cookers and crop dryers, hydraulic ram pumps, and micro-hydro electricity generation coupled with improved water mills. 8000 solar home systems have been installed so far, subsidised by the central government and the state. The installation of 10000 more home systems and the distribution of 6000 solar lanterns have been approved (LAHDC 2005; See also LEDeG xxxx). As the Ladakh Ecological Development Group puts it (*Op cit.*: p. 7): "there is nothing evolutionary about economic growth and technological development (…). If the political will can be mustered, Ladakh can choose a more ecological development path: a path which could offer the prospect of long-term and sustainable well-being".

[44] One may then wonder what will happen once the road is constructed, in terms of changes in the structure of resource consumption. Further research on the road presently being built in the area may show that it is the chronological sequence between development and road construction that may matter, rather than the presence or absence of roads.

expand biocapacity according to their needs (see also Swiss Agency for Development and Cooperation & Global Footprint Network, 2006). Measures of Ecological Footprints and Biocapacities enable us to represent the interactions between renewable resources' demand and supply, and to theorise the complex, dynamic and dialectical relationship between human populations and their environment.

In a seminal article on sustainable livelihoods, the author notes that "measuring resource sustainability is notoriously difficult", given the "difficulty to link indicators of resource depletion or accumulation (…) to both the temporal dynamics of system resilience (…) and livelihood needs" (Scoones, 1998). The Ecological Footprint has this merit. Ecological Footprints have to be interpreted as time dependent, flexible, related to a particular time, with a particular degree of knowledge and technology (See Detlef & Bouwman, 2005). The Ecological Footprint allows accounting for the complex, dynamic and non-linear nature of humans' interactions with their environment; hence Footprints and biocapacities illustrate unbalances between consumption and supply of biological resources that can regenerate or be depleted by the accumulation of deficits. The environment is seen as being resilient. Yet the biocapacity is not unlimited, but there is some degree of uncertainty regarding the biophysical limits of the system – which justifies a precautionary approach.

The Ecological Footprint has been widely used to point to the unbalance between humans' draw on resources and the capacity of the biosphere to regenerate, leading to dangerously unsustainable outcomes. Yet the Ecological Footprint can also be used to point to innovative solutions. There exists several historical and innovative examples in the North and in the South that show how Ecological Footprints can be reduced, but also how the biocapacity can be increased. More longitudinal studies on such examples using the Ecological Footprint are needed, in order to contribute to bringing solutions to the crisis the Ecological Footprint has so far been pointing at.

Tables and Illustrations

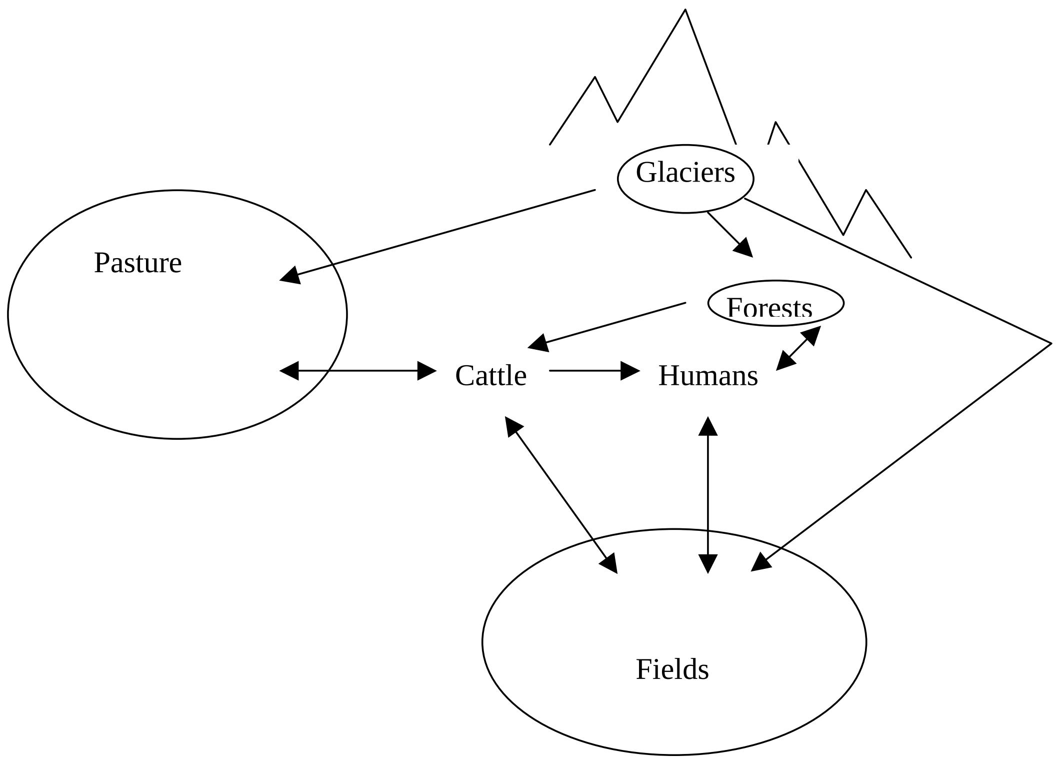

Figure 1: Ladakh's agro-ecological system

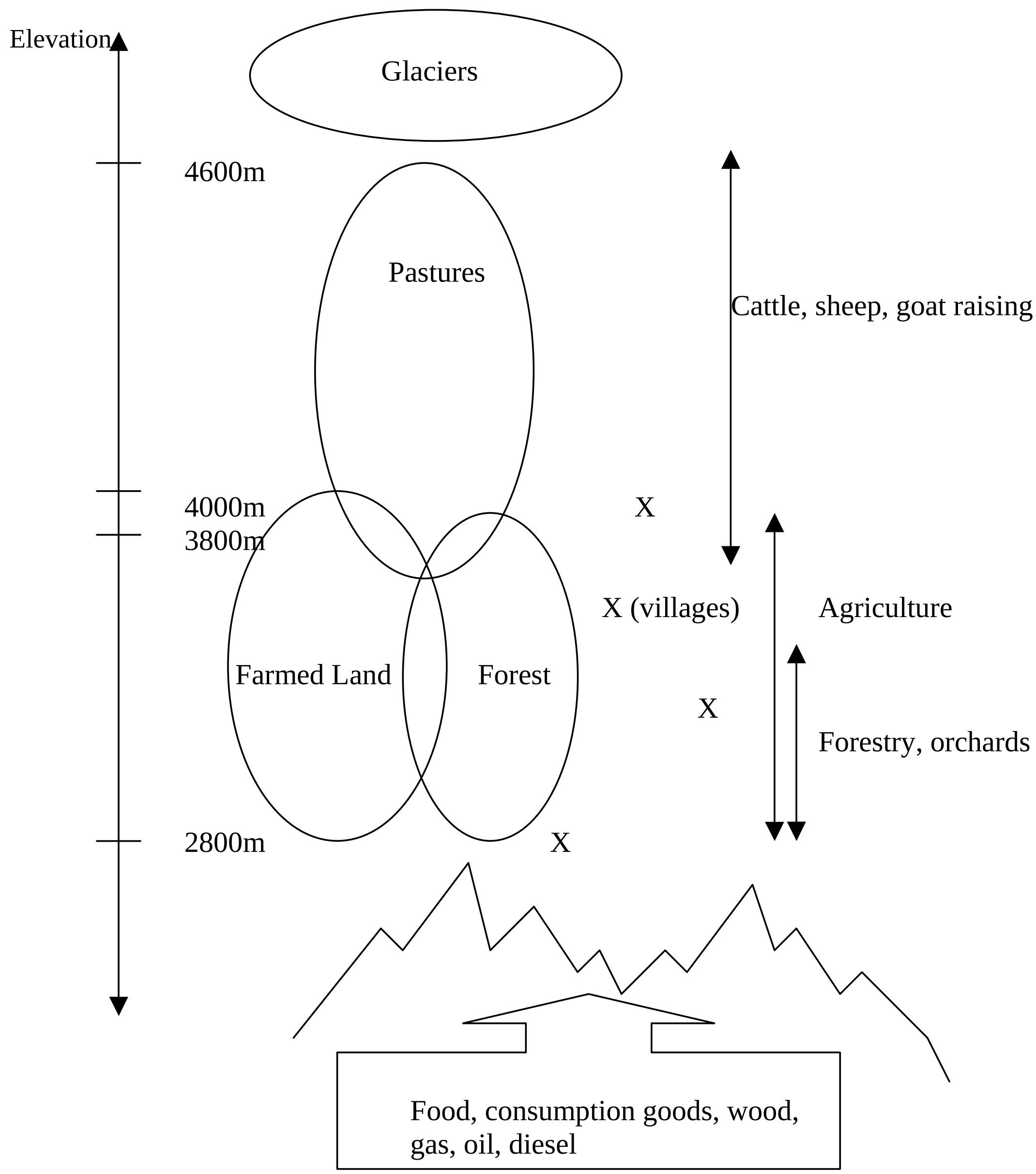

Figure 2: Elevation and resources

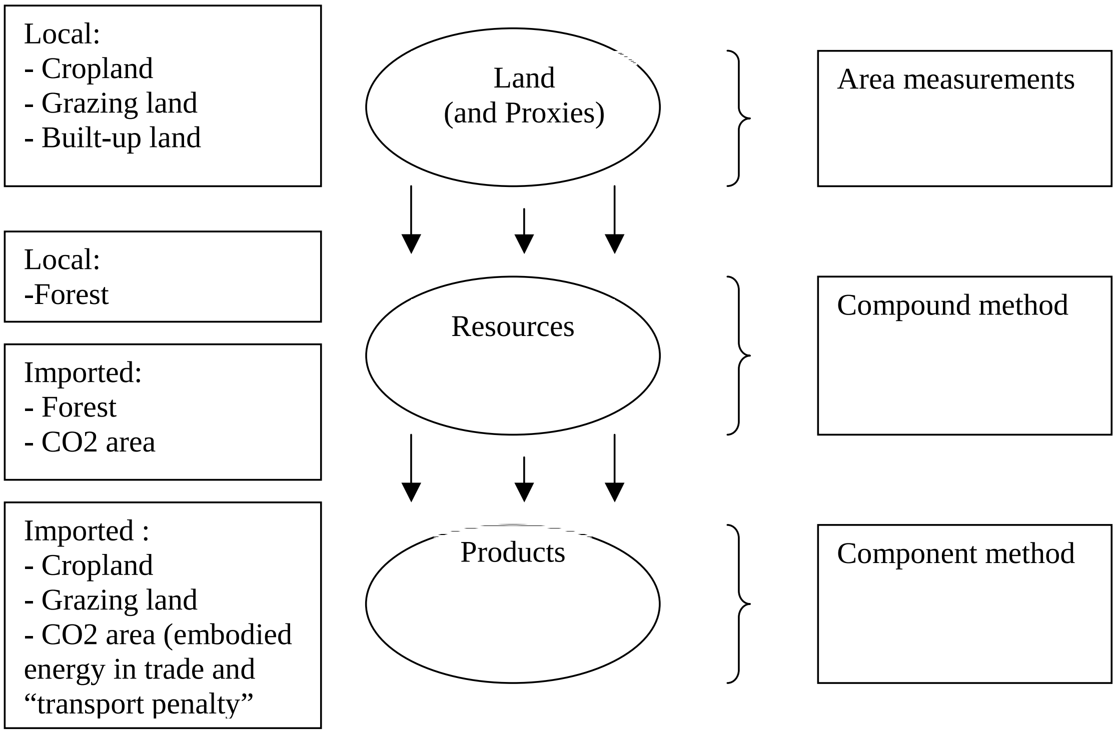

Figure 3: Categories of data and calculation methods

	Equivalence Factor [gha/ha]	Yield Factor (local footprint) [-]	Yield Factor (imported footprint) [-]
CROPLAND	2.18	1.00	1.00
GRAZING L.	0.48	0.34	1.00
FOREST	1.37	0.62	1.00
BUILT-UP L.	2.18	1.00	1.00

Table 4: Conversion factors

Estimating Barley and Wheat yields

There are lot of misconceptions about traditional farming in Ladakh, and giving a figure for average barley and wheat yields is a fairly difficult task. As Osmaston (1994b, pp. 161-162) puts it, “the harsh environment and apparently simple subsistence agriculture in Zanskar [and Ladakh] have led most visitors and government officials to assume that the local crops are rather unproductive”. Hence, official statistics in 1961 give the figure of 0.7 t/ha (Ibid). In 2004, I was given the figure 1.6 t/ha (80kg/kanal) by the Revenue Office (Leh, 30.07.04). However, as Osmaston writes (Ibid) “farmers the world over are reluctant to admit how well their crop can grow in case it is used as an excuse for increased taxation”. Serious evidence suggests that yields are a lot higher than this.

Hence, Osmaston’s thorough investigations based on measurements in Zanskar (Op cit. p. 168) lead to estimations of yields ranging from 2 to 11 t/ha for the best fields. Osmaston, keeping a conservative figure, gives an average of 3 t/ha. Mankelow (2003b) found average yields of 5.2 t/ha for the Padum plain, Zanskar. According to the information gathered from my survey (figures for production and fields were given by farmers), yields in the Trans-Singe La region would be slightly above 3.2 t/ha, and around 2.6 t/ha in Alchi and Saspol.

Yields are also highly variable depending on the village, ranging from an average of 900 kg/ha in Photoksar to 3.9 t/ha in Nierak and 4.4 t/ha in Lingshed. Yields also vary from year to year. In Alchi and Saspol, 2004 was considered a bad year: because of water scarcity, harvest took place early in the summer and yields were half those of the previous year. Yields also vary from one field to an other, depending on altitude, geology, geomorphology, orientation, soil, sowing rates, quantity of manure among other factors (Osmaston 1994b).

Although our method of calculation of Ecological Footprint avoids the use of yields to compute the local Footprint, yields are however needed to obtain the yield factor. This latter is needed in order to convert Ecological Footprint in local hectares to Ecological Footprint in global hectares, and to compute the biocapacity. The variability of yields becomes therefore problematic. Given the variability in ecosystems, topography, and soil characteristics, there is every reason to expect extremely different yields in different places in Ladakh. Consequently it cannot be inferred that the figures obtained from our fieldwork are representative of average yields in Ladakh.

We chose the conservative figure of 2.6 t/ha, as a compromise between official figures and the various data found both in the literature and in our collected data. This figure corresponds to the yields measured in Alchi and Saspol. It also corresponds to the average world yield, thus making Ecological Footprint and biocapacity computations easier.

Table 5: Estimating Yields

	Equivalence Factor [gha/ha]	Yield Factor [-]
CROPLAND	2.18	1.00
PASTURE	0.48	0.34
FOREST	1.37	0.62
BUILT	2.18	1.00

	Local footprint (at local yields)*		Imported footprint (at World yields)**		Ecological Footprint
	(ha/cap)	(gha/cap)	(ha/cap)	(gha/cap)	(gha/cap)
CROPLAND	0.14	**0.30**	0.06	**0.13**	**0.43**
PASTURE	1.36	**0.22**	0.06	**0.03**	**0.25**
FOREST	0.07	**0.06**	0.04	**0.06**	**0.11**
BUILT	0.00	**0.01**	-	**-**	**0.01**
ENERGY (forest)	-	-		**0.33**	**0.33**
TOTAL		**0.58**		**0.55**	**1.12**

* The footprint in standardized hectares (gha) is obtained by multiplying the local footprint (ha) by its respective equivalence factor and yield factor.

** The footprint in standardized hectares (gha) is obtained by multiplying the imported footprint (ha) by its respective equivalence factor. Imported footprints have a yield factor of 1, as results are obtained at world productivity.
Energy footprint is already given in global hectares

Table 6: Ecological Footprint of Alchi-Saspol

	Equivalence Factor [gha/ha]	Yield Factor [-]
CROPLAND	2.18	1.00
PASTURE	0.48	0.34
FOREST	1.37	0.62
BUILT	2.18	1.00

	Local footprint (at local yields)*		Imported footprint (at World yields)**		Ecological Footprint
	(ha/cap)	(gha/cap)	(ha/cap)	(gha/cap)	(gha/cap)
CROPLAND	0.09	**0.21**	0.02	**0.04**	**0.24**
PASTURE	2.14	**0.34**		**0.00**	**0.35**
FOREST	0.08	**0.07**	0.00	**0.00**	**0.07**
BUILT	0.01	**0.01**			**0.01**
ENERGY (forest)	-	-		**0.01**	**0.01**
TOTAL		**0.63**		**0.05**	**0.69**

* The footprint in standardized hectares (gha) is obtained by multiplying the local footprint (ha) by its respective equivalence factor and yield factor.

** The footprint in standardized hectares (gha) is obtained by multiplying the imported footprint (ha) by its respective equivalence factor. Imported footprints have a yield factor of 1, as results are obtained at world productivity.
Energy footprint is already given in global hectares

Table 7: Ecological Footprint of the Trans-Singe La region

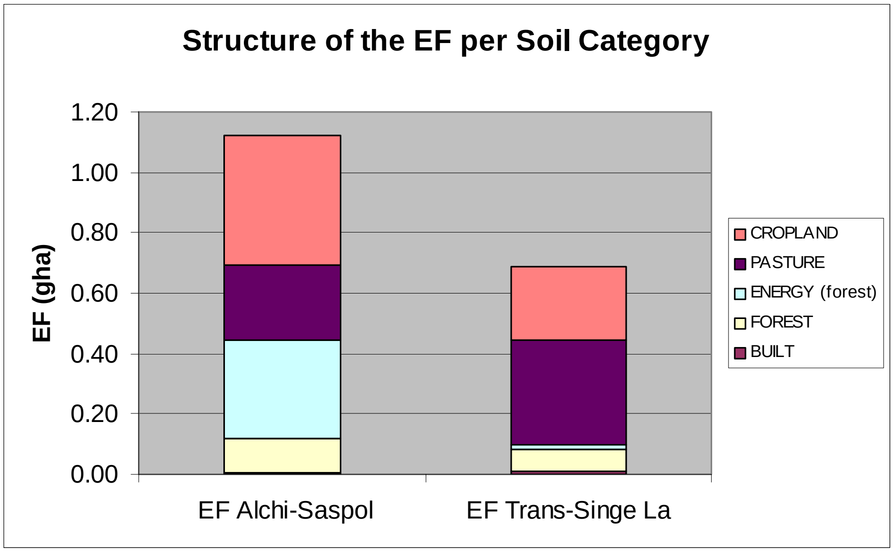

Figure 8: Ecological Footprints by category of soil

	Actual Local Biocapacity*		Potential Local Biocapacity*		World Biocapacity**	
	(ha/cap)	**(gha/cap)**	(ha/cap)	**(gha/cap)**	(ha/cap)	**(gha/cap)**
CROPLAND	0.09	**0.20**	0.38	**0.84**	0.25	**0.54**
PASTURE	1.45	**0.23**	1.45	**0.23**	0.57	**0.27**
FOREST	0.10	**0.09**	0.10	**0.09**	0.59	**0.81**
BUILT-UP	0.02	**0.05**	0.02	**0.05**	0.03	**0.07**
(FISHERIES)	-	-	-	-	0.37	**0.13**
(Equivalence factor: 0.36)						
TOTAL	Actual	**0.57**	Potential	**1.21**	World Biocapacity	**1.82**

* The biocapacity in standardized hectares (gha) is obtained by multiplying the local biocapacity in hectares (ha) by its respective equivalence factor and yield factor.

** The world biocapacity in standardized hectares (gha) is obtained by multiplying the biocapacity of each type of land in hectares (ha) by its respective equivalence factor. World biocapacities have a yield factor of 1, as results are obtained at average world productivity.

Figure 9: Biocapacity

Local Ecological Deficit

	Local footprint (gha/cap)	Local Biocapacity (gha/cap)	Local Ecological Deficit (gha/cap)
Alchi-Saspol	0.58	0.57	-0.01
Trans-Singe La	0.63	0.57	-0.06

Table 10: Local ecological deficit

Total Ecological Deficit

	Ecological Footprint (gha/cap)	Local Biocapacity (gha/cap)	Ecological Deficit (gha/cap)
Alchi-Saspol	1.12	0.57	-0.55
Trans-Singe La	0.69	0.57	-0.12

Table 11: Total ecological deficit

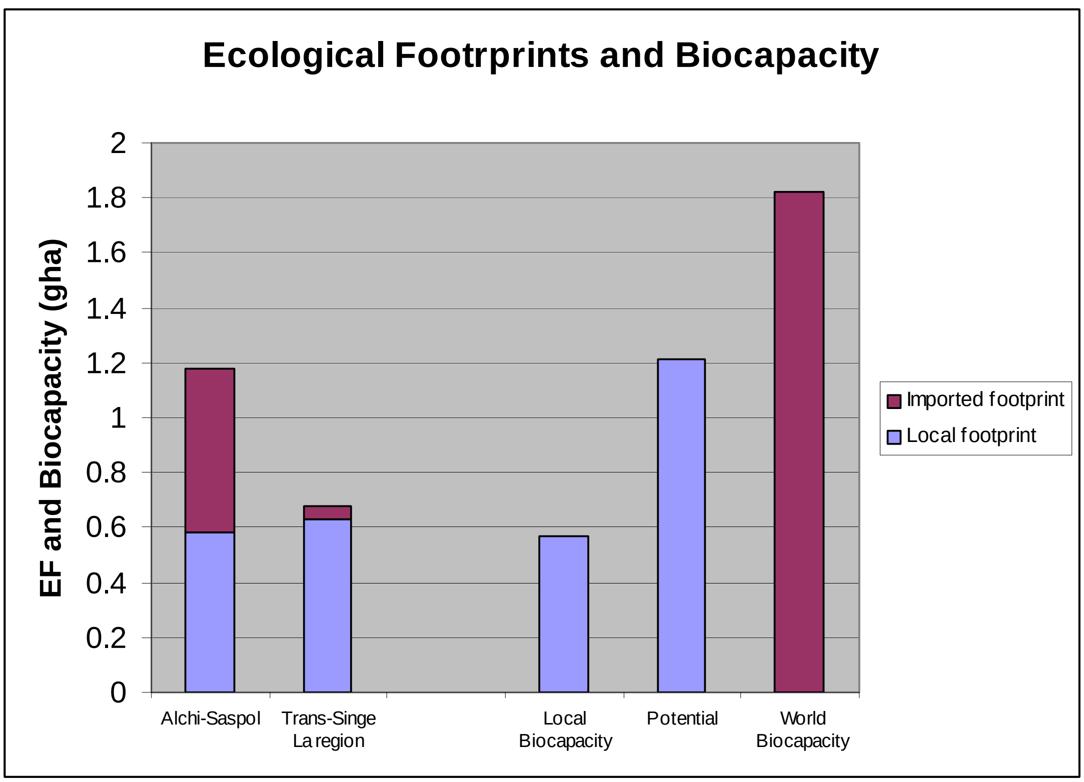

Figure 12: Ecological Footprints and Biocapacity

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