Livestock Research for Rural Development 25 (7) 2013 | Guide for preparation of papers | LRRD Newsletter | Citation of this paper

Livestock intensification and use of natural resources in smallholder mixed farming systems of Bhutan

T Samdup, Henk M J Udo*, Theo C Viets* and Akke J van der Zijpp*

Council for Renewable Natural Resource Research of Bhutan, Thimphu, Bhutan
tashi_samdup2001@yahoo.com
** Wageningen University, The Netherlands*

Abstract

Bhutan aims to intensify livestock production not only to improve livelihoods of farming households and to meet the increasing demands of livestock products, but also to sustainably use natural resources. This paper assesses the impact and trends of livestock intensification on the use of Common Property Resources (CPR), and how this affects the cattle numbers that can be maintained and the nitrogen (N) and phosphorus (P) flows at the farm. Data on household, cropping and livestock activities were collected through interviewing 183 households in extensive, semi-intensive, intensive, and intensive peri-urban areas in the years 2000 and 2004.

In the extensive and semi-intensive areas, CPR was the most important source of Total Digestible Nutrients (TDN) for cattle. In the intensive areas with a majority of crossbred cattle, the farmers relied less on CPR than in the other two areas, but still about one quarter of the TDN requirements were met by grazing CPR. Grazing in the CPR provided the highest proportion of NP inputs at farm level; without grazing on CPR all four areas would have had highly negative soil nutrient balances. Intensification of livestock production through crossbreeding has not resulted in major reductions in cattle numbers per farm, but it is contributing to reduced use of CPR by farmers. Intensification partly replaces farm nutrient flows from CPR with nutrient inputs through increased use of concentrates, conserved fodder, and fertilizers. More awareness of nutrient management is required among farmers coupled with more research on nutrient assessments.

Key words: *common property resources, livestock, nitrogen and phosphorus flows*

Introduction

A major challenge for livestock intensification in developing countries is to find a balance between human food needs, livelihoods of farming households and the sustainable use of natural resources. Land is such an important natural resource (de Wit et al 1995). Growing population pressure, fragmentation of land due to inheritance, and land encroachment due to urbanization all contribute to reducing land sizes per farming household. In Bhutan only about 8% of the land is suitable for arable farming and about 4% is pasture land (LUPP 1997). Therefore, farmers closely integrate livestock and crop production with forestry. The forests are state owned, but farmers do have legal grazing rights in some of the forest areas. Environmentalists and foresters routinely view cattle grazing as a serious threat to biodiversity, through reduction of undergrowth, and change in structure and tree species composition (Rosset 1997). Others argue that quantitative observations do not support these assertions because removal of herbaceous biomass by grazing enhanced conifer species regeneration, though grazing did diminish the number and density of broadleaved species (Roder et al 2002).

In Bhutan, intensification of livestock production has to consider the fragility of the alpine ecosystems. Crossbreeding for dairy production is the major tool in livestock intensification (Samdup et al 2010). Concurrent efforts are made to promote and enhance pasture, feed and fodder development programmes (MoA 2002). One of the objectives, next to meeting the demands for dairy products and contributing to the development of rural households, is to reduce grazing in Common Property Resources (CPR) by keeping fewer but more productive cattle. It is expected that crossbreeding will bring the livestock density in line with the carrying capacity of the farm land and CPR (Dorji 1993; Roder et al 2001). The traditional combination of grazing in the CPR and night feeding near the farmer's house contributes considerably to the maintenance of soil fertility at farm level; on the other hand, it results in continuous export of plant nutrients from the forest (Roder et al 2002). Intensification of livestock is expected to replace farm nutrient inputs from forest areas with nutrient inputs through increased use of fertilizers and concentrates (Samdup et al 2010).

Quantitative studies on the impact of livestock on the use of natural resources in Asia are scarce (Pilbeam et al 2000; Thorne and Tannner 2002). This paper aims to assess the impact of livestock intensification on the use of CPR, and the cattle feed balance and the Nitrogen (N) and Phosphorus (P) flows at the farm level in four geographical areas differing in agro-ecological conditions, infrastructure, market access and consequently crossbreeding implementation.

Material and Methods

Study areas

Bhutan is located in the Eastern Himalayas, bordered by the Tibetan region of China and India. The study areas were in Khaling block in Trashigang district, Dala block in Chukha district, Chokhor block in Bumthang district and Chang block in Thimphu district, located in east, south, central and west Bhutan respectively. A block consists of a number of villages. The Khaling study area represented Bhutan's 'extensive' farming system characterised by mainly local Siri cattle grazing in the forest and on natural grasslands with some night feeding, no crop irrigation, a mild temperate climate, and poor market access (no motorable road, 4-5 h needed by vehicles to reach large markets). The Dala study area represented a 'semi-intensive' farming systems with Siri and crossbred (Siri x Jersey) cattle in equal proportions, mainly grazing with some stall feeding, limited commercial concentrate feeding, some irrigation, and medium market access (no regular transport services, 2 h needed for vehicles to reach large markets). The Chokhor and Chang study areas represented 'intensive' farming systems: Siri x Brown Swiss crossbred cattle in Chokhor and Siri x Jersey crossbreds and Jersey in Chang coupled with stall feeding, high commercial concentrate feeding, use of inorganic fertilizers, and irrigation. The Chang area is close (20-30 min.) to the capital city Thimpu and represents a peri-urban area. Many farmers in the intensive areas were members of dairy groups for the collective marketing of milk.

The soils are mainly clay and clay loam types. The major crops grown were maize and potatoes in the extensive area, maize and rice in the semi-intensive area, buckwheat, potatoes and apples in the intensive area, and rice and apples in the intensive peri-urban area. Cattle provide milk, milk products, manure and draught power. Most cattle graze in the tsadrogs (registered grazing land) located near settlements or in forests during the day, and are confined to houses or crop fields at night. Sometimes, crossbred milking cows or those in advanced gestation are kept at the farm during the day. Conservation of fodder (hay and silage) was done in moderate quantities in the intensive areas.

The 1985 national cattle breeding policy differentiated between the agro-ecological zones: it proposed Brown Swiss crossbreeding in the high altitudes; Jersey crossbreeding in other areas with relatively better market access; and using local breeds in remote areas that have harsh environmental conditions. In 1998, in response to farmers' requests, the cattle breeding policy was changed to provide semen and bulls of any breed to all districts based on farmers' demand.

Data collection

A two-phase time series household survey was carried out in which the same households were visited in 2000 and 2004. Data were collected for these two years to capture the impact and trends due to the breeding policy change of 1998. In total, 183 households from 37 villages were selected at random. Based on the 2000 census (DoL2001), in each block 30-40% of the villages (6, 9, 16 and 6 villages in Khaling, Dala, Chokhor and Chang blocks, respectively) and in each village 5-15% of the households (63, 35, 55 and 30 households in Khaling, Dala, Chokhor and Chang respectively) were visited. Weather conditions were comparable in both survey years.

Recall data covering one year were collected through household interviews by trained enumerators using a pre-tested, semi-structured questionnaire. Individual farmers were interviewed on family background, sources of income, land-use, crop and livestock management practices, crop production, and milk off-take. For each farm, external and internal flows of nutrients N (nitrogen) and P (phosphorus) (Figure 1) were quantified for 2000 and 2004.

Assessment of farm feed balance

In this study, the Farm Feed Balance (FFB) is calculated as the number of standardised tropical livestock units (TLU) of 300 kg body weight that can be maintained by the on-farm and off-farm feed resources and grazing in CPR in terms of Total Digestible Nutrients (TDN) requirements (Thapa and Paudel 2000). Cows, bullocks, and bulls were considered as 1 TLU, heifers and young bulls as 0.7 TLU and calves as 0.2 TLU (Samdup, 1997; DALSS, 2001). A model approach was used to estimate the average FFB in the farms in the four areas based on a comparison of the TDN requirements of the animals with the TDN available from external feed supply, on-farm feed availability, and grazing on CPR and pasture land. A scenario of the FFB without CPR grazing was also analysed to explore the impact of CPR on livestock feeding at farm level.

TDN requirements

The TDN requirements for cattle were taken from Joshi (1988). Table 1 gives the daily maintenance and production requirements in kg TDN for different types of cattle. The TDN requirements were estimated by summing the total nutrient requirements for maintenance and production functions. Milk of crossbred and local cattle was estimated to contain 3.5% and 5% fat respectively. Gestation requirements were taken for the last trimester. In the intensive and intensive peri-urban area the average lactation length of cows was obtained from milk recording data, these were 277 days and 289 days, respectively. Such information was not available for the semi-intensive and the extensive area; as such lactation lengths of 277 and 243 days respectively, were estimated based on information by the farmers during the field survey. Concentrates were fed to lactating cows, cows in the last trimester of gestation, breeding bulls, and working bullocks. The survey showed that bullocks worked 27, 41, 21 and 14 days per year in the extensive, semi-intensive, intensive, and intensive peri-urban areas, respectively. Breeding bulls were given additional feed in the extensive area for 90 and in the other areas for 60 days per year.

Table 1: Maintenance and production requirements of Total Digestible Nutrients (TDN) in kg per livestock unit (LU) per day

	Type of requirements	TDN (kg)
Cows	Maintenance	2.36
	Gestation	0.7
	Production (milk per kg with 3.5% fat)	0.29
	Production (milk per kg with 4.5% fat)	0.34
Growing animals[1]	Maintenance &growth	
	Calves	1.9
	Heifers and young bulls	2.6
Breeding bulls	Maintenance & breeding	3.6
	Maintenance	2.36
	Breeding	1.24
Bullocks	Maintenance & draft	3.1
	Maintenance	2.36
	Draft	0.74

[1]*heifers, young bulls and calves*

TDN available

The DM and TDN content of the feeds for cattle were taken from Sen et al (1978). The annual TDN available was calculated per farm in the four study areas. The annual TDN available from concentrates ($Conc_{TDN\ avail}$) was calculated based on data available from the survey and literature and was estimated as: $Conc_{TDN\ avail} = Conc_{DM\ avail} * Conc_{TDN\ content}$; where $Conc_{DM\ avail}$ is the total dry matter (DM) available from concentrates; $Conc_{TDN\ content}$ is the TDN content per kg DM of concentrates (Singh 2003). The above equation was also used to estimate the annual TDN available from crop residues, fodder tree leaves, and hay and silage.

CPR refers to grazing in the forests and natural grasslands. Farmers generally agreed that CPR provide a large proportion of their animal feed requirements. Based on the interviews with farmers, it was estimated that cattle grazed in the CPR for 365 days in the extensive area, 330 days in the semi-intensive area and 300 days in the intensive areas. Cattle grazed on average, 6.5 h in the intensive areas and 8 h in the semi-intensive and extensive areas.

The grazing practices were similar in 2000 and 2004. Based on estimates of Roder (1990) and RGOB (1994) the proportion of DM maintenance requirements met from grazing in the CPR was taken as 61% in the extensive area, 52% in the semi-intensive area and 44% in the intensive and intensive peri-urban areas.

The annual TDN available from CPR ($CPR_{TDN\ avail}$) was estimated as:

$CPR_{TDN\ avail} = CPR_{PMR} * MR * CPR_{days} * Grass_{TDN\ content} * TLU$, where CPR_{PMR} is the proportion of maintenance requirements met from CPR; MR is the DM maintenance requirement per TLU in kg d^{-1}, which is estimated as 2 % of the body weight (300 kg); CPR_{days} is the number of days cattle graze in CPR per year; $Grass_{TDN\ content}$ is the TDN content per kg DM of grass.

The TDN available from on-farm pasture land ($Pasture_{TDN\ avail}$) was estimated as:

$Pasture_{TDN\ avail} = Pasture_{DM\ avail} * Pasture_{TDN\ content}$, where $Pasture_{DM\ avail}$ is the total DM available in the pasture land per year. This was calculated based on the assumption that the average DM available from improved pasture in Bhutan is 4000 kg per ha (Roder et al., 2001) and from local pasture 654 kg per ha (Dorji, 1993). $Pasture_{TDN\ content}$ is the TDN content per kg DM of pasture (Dorji 1993).

Nutrient (NP) inputs to livestock sub-system

All NP inputs and outputs were computed on DM basis. The annual NP input into the livestock sub-system was computed in the same way as for the TDN intake. The nutrient inputs were commercial concentrates (ready-made), procured feed ingredients (e.g. maize, rice bran, mustard oil cakes), pasture grazing and crop residues from the crop sub-system. Commercial concentrates were fed to cattle only in the intensive and intensive peri-urban areas. Local concentrates are prepared using locally available feed sources and some procured feed ingredients.

Nutrient outputs from livestock sub-system

The annual NP outputs from the livestock sub-system and crop sub-system were estimated using the equations described below:

The annual NP output of milk (Milk $_{NP\ output}$) was estimated as: Milk $_{NP\ output}$ = Milk $_{yield}$ * Milk $_{NP\ content}$, where Milk $_{yield}$ is the quantity of milk per year; Milk $_{NP\ content}$ is the N or P content of milk taken at 0.6 and 0.09%, respectively (Wortman and Kaizzi 1998).

The annual NP output from animals sold (Animal $_{NP\ output}$) was estimated as: Animal $_{NP\ output}$ = TLU $_{sold}$ * TLU $_{NP\ content}$; where TLU $_{sold}$ is the total TLU kg sold per year; TLU $_{NP\ content}$ is the NP content of TLU taken at 25.3 g N and 7.4 g P per kg body weight (van Eerdt 1994). The same equation was used to derive at estimates for animals that died.

The estimation of the quantity of manure produced was based on the assumption that one TLU consumes about 6 kg DM per day (2% of body weight) (Samdup et al 2010). With an assumed DM digestibility of 60%, it was estimated that the annual manure production was 880 kg DM per LU. With the N, P and K content of manure taken at 1.6%, 0.8% and 1.2% on DM basis, respectively (ICAR 1986), the annual N, P and K content of manure per TLU was estimated at 14 kg, 7 kg and 11 kg, respectively. Nutrient losses of NPK during storage were estimated as 50% for N and P and 40% for K (Moore and Garroth 1993). Based on the average number of hours grazed per day in the CPR, it was assumed that 27% to 33% of the manure was deposited on the CPR and the remainder on the farm land.

Nutrient outputs from crop sub-system

The total crop sub-system output is the sum of NP outputs from crops and on-farm pasture land grazing. The annual total NP output of the Crops (Crops $_{NP\ output}$) was estimated as:

Crops $_{NP\ output}$ = Crop $_{yield}$ * Crop $_{NP\ content}$, where Crop $_{yield}$ is the quantity of grains, crop residues, hay and silage DM from orchard land; Crop $_{NP\ content}$ is the NP content of the crop sub-system outputs. The NP contents of crop products were derived from literature in Bhutan and neighbouring Nepal (Tamang 1988; Roder et al 2001; Roder et al 2003). A harvest index of 0.43 for fine grain crops (Pezo, 2002; Schiere et al., 2004) and 0.30 for coarse grain crops (Pezo 2002) was used for calculation of the straw:grain ratio.

Pasture land is considered as a part of the crop sub-system. The annual NP output from pasture grazing as an input into the livestock sub-system per farm was estimated as: Pasture $_{NP\ avail}$ = Pasture $_{DM\ avail}$ * Pasture $_{NP\ content}$, where Pasture $_{DM\ avail}$ is the total DM available in the pasture land per year (Dorji 1993). Pasture $_{NP\ content}$ is the NP content per kg DM of pasture (Tamang 1988; Roder et al 2001; Roder et al 2003).

Estimated ammonia losses and crop harvest losses

Ammonia losses from the application of manure to soil were taken as 18.5% (Van der Hoek 2002). As much as 50% of nitrogen and phosphorus can be lost from manure through run-off, leaching and mixing with the soil on the plot surface (Tamminga 1992; Moore and Garroth 2003). Since most of the manure in Bhutan is stored in the open, the NP losses were estimated to be 50%. Ammonia losses from inorganic fertilisers through leaching and volatilisation were estimated at 13%, as was reported in the mid hills of Nepal (Singh et al 1991). Ammonia losses during processing and preservation of the crops to be used as animal feed were estimated at 5% of the total nitrogen content of the crops (de Boer et al 1997).

Crop harvest losses which remain on the field and go to the soil were estimated as 15% of the total uptake by the crops, and ammonia losses during decomposition of crop harvest losses were estimated at 20% (de Boer et al 1997).

Nutrient balances

Figure 1 gives the conceptual model used to show the NP flows per farm. The nutrient balances resulted from processes and flows managed by the farmer, so they did not include soil erosion, sedimentation and nitrogen fixation.

The annual NP balances for the crop sub-system (CSS $_{NP\ balance}$) of the farms in the four areas were estimated as: CSS $_{NP\ balance}$ = CSS $_{NP\ inputs}$ - CSS $_{NP\ outputs}$, where CSS $_{NP\ inputs}$ are the manure inputs from the livestock sub-system to the soil plus fertilizers; CSS $_{NP\ outputs}$ are the outputs of the crop sub-system (crop products, crop harvest to soil, crops and pasture to the livestock sub-system).

The farm nutrient balances (FS $_{NP\ balance}$) are a result of the external nutrient (NP) inputs minus the external nutrient outputs (NP) (Figure 1). This was estimated as: FS $_{NP\ balance}$ = LSS $_{NP\ ext\ inputs}$ + CSS $_{NP\ ext\ inputs}$ - LSS $_{NP\ outputs}$ - CSS $_{NP\ outputs}$, where LSS $_{NP\ ext\ inputs}$ are the external NP inputs into the livestock sub-system (concentrates, feed ingredients and grazing in CPR); CSS $_{NP\ inputs}$ are the external NP inputs into the crop sub-system (inorganic fertilizers); LSS $_{NP\ outputs}$ are the NP outputs of the livestock sub-system going out of the farm system (milk, animal sold or died and manure going to CPR); CSS $_{NP\ outputs}$ are the outputs of the crop sub-system going out of the farm.

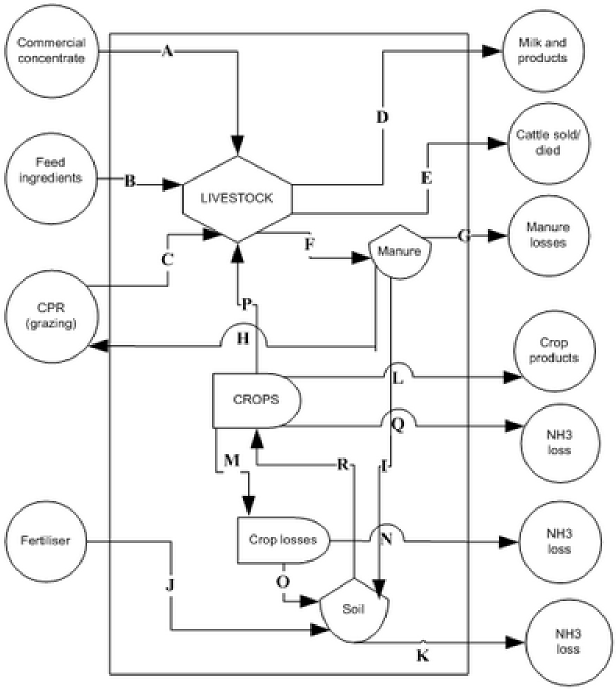

Figure 1: Flow chart of inputs and outputs of Nitrogen (N) and Phosphorus (P) for farms with a crop and livestock sub-system; symbols according to Odum (1983); the labels indicate the flows that are quantified in Tables 3 and 4

Statistical analyses

Least-squares methods (Harvey 1977) were used to explain variation in farm characteristics, and farm inputs and farm outputs between study areas. A nested design was also used with years nested within study areas (least square differences 2004-2000).

Results

Land use and livestock keeping

Table 2 gives the least square means (lsm) and the change from 2000 to 2004 (lsd) of available farm resources, annual fertilizer use, and annual crop and livestock production in the four areas. The farms were significantly larger in the intensive (2.9 ha) and semi-intensive (2.6 ha) areas compared to the extensive (1.2 ha) and intensive peri-urban (1.3 ha) areas. Land was used mainly for cropping. There was a decline in land area (0.44 ha) in the intensive peri-urban area in 2004 compared to 2000 due to the sale of land for expansion of Thimpu city. This also resulted in a significant decline in herd size in this area. Herd size was highest in the intensive area (9.4 TLU). These herds were composed of 85% crossbred cattle, in contrast to the herds in the extensive area which were composed of 23% crossbreds. A significant decline in herd size in the extensive and intensive peri-urban areas in 2004 was seen only for local cattle. The numbers of crossbred cattle did not change between 2000 and 2004.

Table 2: Farm resources, crop and livestock production in four areas of Bhutan, averages (least square means, lsm) and change from 2000 to 2004 (least square differences 2004-2000, lsd).

Area/ System	Khaling/ Extensive		Dala/ Semi-intensive		Chokhor/ Intensive		Chang/ Int. peri-urban			
Nutrient flows	lsm	lsd	lsm	lsd	lsm	lsd	lsm	lsd	s.e[1]	s.e[2]
Total land (ha)	1.3^b	0	2.6^a	-0.1	2.9^a	0.01	1.3^b	-0.37	0.2	0.3
Crop land (ha)	1.1^b	0	2.4^a	-0.2	2.0^a	0	1.2^b	-0.4	0.2	0.2
Pasture land (ha)	0.2^b	0	0.2^b	0.1	0.9^a	0	0.1^b	0	0.1	0.1
Herd size (TLU)	7.3^b	-1.6^z	7.1^b	-1.6	9.4^a	-0.2	5.3^c	-3.5^z	0.4	0.6
Crossbred	1.7^c	0	4.2^b	-0.3	8.1^a	0.1	4.0^b	-2.1	0.3	0.5
Local	5.7^a	-1.6^z	3.0^b	-1.4^z	1.4^c	-0.3	1.4^c	-1.4^z	0.3	0.4
Inorganic fertilizer (kg x 100)										

Urea	1.0^{c}	0.4	0.3^{d}	0.6	2.7^{a}	0.5	1.6^{b}	-0.4	0.001	0.001
Single superphosphate	0.9^{b}	0.1	-	-	5.0^{a}	1.0^{z}	0.4^{c}	-0.1	0.001	0.002
Potash	-	-	-	-	0.1^{a}	0	0.3^{a}	-0.1	0.002	0.001
Crop produce (kg x 100)										
Rice	-	-	6.3^{b}	1.6^{z}	-	-	17.2^{a}	-11.0^{z}	0.002	0.001
Wheat	-	-	-	-	2.5^{a}	0.9^{z}	0.5^{b}	0.1	0.002	0.001
Barley	-	-	-	-	1.5^{a}	0.3	-	-	0.002	0.002
Buckwheat	-	-	-	-	20.2^{a}	9.4^{z}	-	-	0.001	0.001
Maize	14.5^{a}	1.1	6.5^{b}	2.1	-	-	-	-	0.002	0.001
Potatoes	27.9^{b}	3.5	2.4^{c}	0.7	42.6^{a}	3.5	3.9^{c}	-1.1	0.001	0.001
Apples	-	-	-	-	8.2^{b}	-0.9	30.2^{a}	-0.9	0.002	0.001
Livestock produce (kg x 100)										
Milk off-take	12.9^{c}	-0.2	30.5^{b}	3	44.5^{a}	11.0^{z}	46.0^{a}	-14.0^{z}	0.002	0.001
Butter	0.6^{b}	-0.1	0.5^{b}	0.2	1.4^{a}	0.4^{z}	0.5^{b}	-0.2^{z}	0.002	0.001
Cheese	1.1^{b}	-0.1	1.0^{b}	0.5	2.5^{a}	0.7^{z}	0.9^{b}	-0.3^{z}	0.001	0.001

^{a,b,c,d}*lsm with different superscripts between study areas are different (p<0.05).*
^{z}*lsd within a study area is different (P<0.05).*
^{1}*s.e of an average between areas,* ^{2}*s.e of an average between years within an area.*

The annual fertilizer inputs differed significantly between the four areas with the highest fertilizer use in the intensive area (780 kg per farm or 268 kg per ha crop land) and the lowest use in the semi-intensive area (30 kg per farm or 13 kg per ha). In the intensive area the use of fertilisers was significantly higher (21%) in 2004 compared to 2000. Annual rice production was significantly higher in the intensive peri-urban area (1720 kg per farm or 1433 kg per ha crop land) than in the other areas. There was a significant decrease in rice production (48%) in the intensive peri-urban area in 2004 compared to 2000 (Table 2) which was due to the decrease in farm size. In the intensive area there was a significant increase in annual wheat (45%) and buckwheat (61%) production in 2004, probably due to increased use of inorganic fertilizers. In the semi-intensive area, there was a significant increase in rice production (21%) in 2004 also due to increased use of inorganic fertilisers.

The intensive areas had significantly higher milk off-take per farm compared to the farms in the extensive and semi-intensive areas. In the intensive area there was a significant increase in milk off-take per farm (28%), and in the intensive peri-urban area a significant decrease in milk off-take per farm (26%) in 2004 compared to 2000. Butter and cheese production was significantly higher in the intensive area than in the other three areas.

Feed resources and farm feed balance

Figure 2 gives the different sources of feed available per farm in kg TDN for the four study areas in 2000 and 2004. In 2000, the contribution of CPR grazing to the TDN available per average farm ranged from 25% in the intensive peri-urban area to 62% in the extensive area. In 2004 the contributions of CPR grazing to TDN available had slightly decreased to 19% in the intensive peri-urban area and 51% in the extensive area. In the intensive and intensive peri-urban areas, concentrates were the next most important source of TDN and contributed 21 and 35%, respectively, to the total TDN available. In the extensive and semi-intensive areas, crop residues were the second most important TDN source, contributing 24 and 34%, respectively, to the total TDN available. Conserved fodder was only fed in the intensive areas. The reasons given for not using conserved fodder in the extensive and semi-intensive areas were the lack of green grass and the additional labour required. This was compensated by more hours of grazing in the CPR. In the semi-intensive area, fodder trees were an important source of feed providing about 20% of the total TDN available.

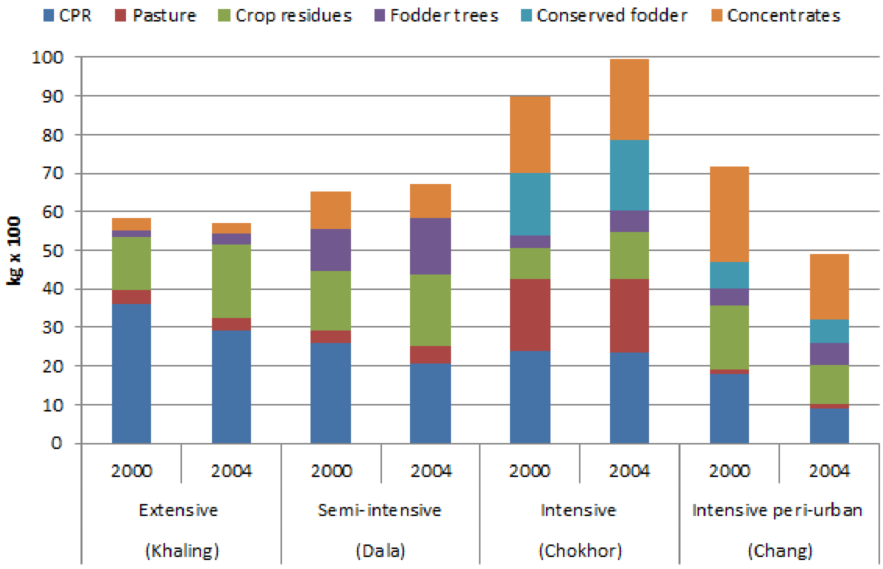

Figure 2: Contribution of Total Digestible Nutrients (TDN) in kg by different sources of feed in the four areas of Bhutan, average in 2000 and 2004

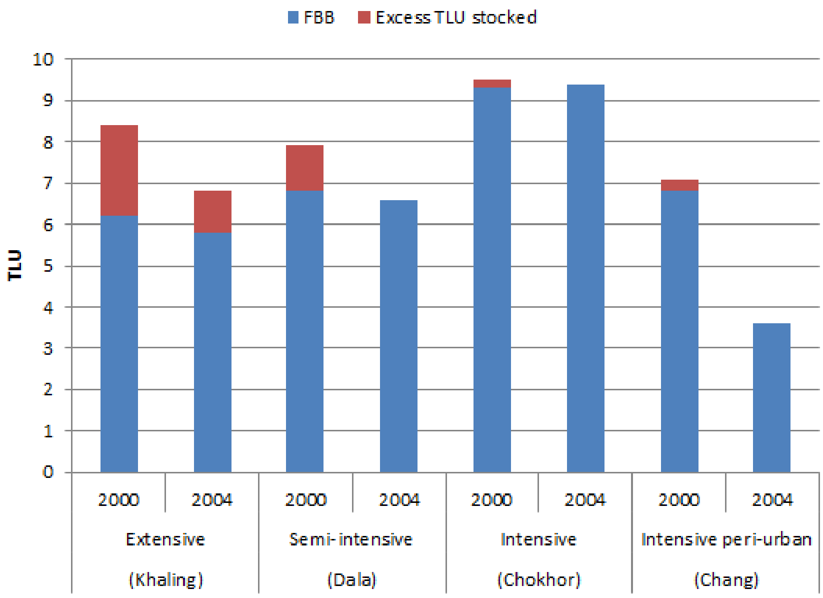

Figure 3: Farm Feed Balance (FFB) and Excess Tropical Livestock Unit (TLU) in four areas of Bhutan in 2000 and 2004

Figure 3 gives the estimated number of cattle maintained in TLU and the excess TLU kept in the farms in the four study areas. In 2000, the excess TLU reared in relation to the feeds on offer ranged from 2.2 TLU or 26% of the total herd size (8.4 TLU) in the extensive area to 0.2 TLU or 2% of the total herd size of 9.5 TLU in the intensive area. In 2004, the TLU's kept matched the feed resources, mainly due to reductions in local cattle numbers in 2004, only the extensive area had excess of 1 TLU (15% of the total herd size).

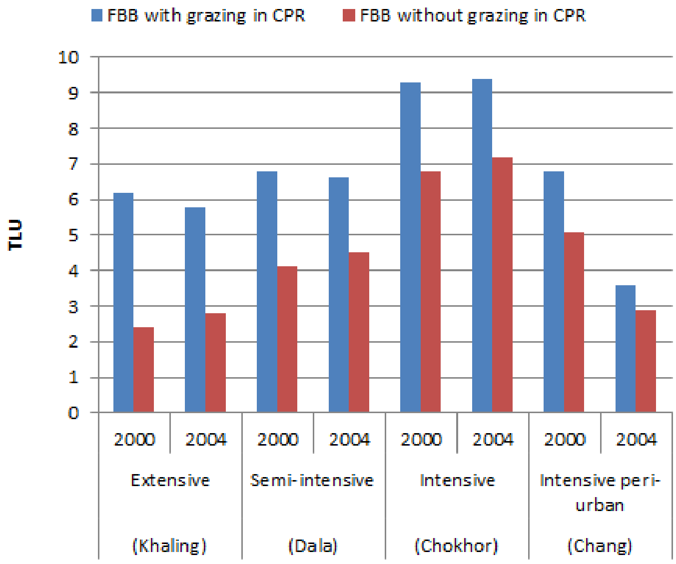

Figure 4: Farm Feed Balance (FFB) with and without grazing in Common Property Resources (CPR) in four areas of Bhutan in 2000 and 2004.

Figure 4 compares the number of cattle that can be maintained with grazing in CPR and without grazing in CPR. It shows the importance of CPR for feeding cattle. Considering a scenario, where there is no grazing in the CPR, then the number of cattle that can be maintained ranged from only 2.4 TLU (extensive area) to 7.2 TLU (intensive area).

Nutrient (NP) flows

Tables 3 and 4 give the NP inputs, outputs and balances (in kg y^{-1}) for the farms in the four areas of Bhutan (lsm) and the change from 2000 to 2004 (lsd). Grazing in the CPR provided the highest NP inputs for cattle. They ranged from 66 kg N and 6 kg P (34% of N inputs and 24% of P inputs) in the intensive peri-urban area to 158 kg N and 15 kg P (73% of N inputs and 62% of P inputs) in the extensive area. There was a significant decline in the N inputs from CPR grazing in the extensive, semi intensive and intensive peri-urban areas in 2004 compared to 2000. For P this decline was significant in the semi-intensive and intensive peri-urban areas. The contribution of concentrates and procured feed ingredients to the NP inputs was significantly higher in the intensive and intensive peri-urban areas than in the other areas. Cattle manure was the main input into the crop sub-system. It was highest in the intensive area due to its large herd size. The NP fertilizer inputs were highest in the intensive area and lowest in the semi-intensive area. In 2000, the semi-intensive area did not use inorganic fertilizers at all. There was a significant increase in N inputs from inorganic fertilizers in the extensive area (38%) and intensive area (22%) in 2004 compared to 2000. Only in the intensive area there was a significant increase in P input (11%) in 2004 compared to 2000.

Manure contributed to over 80% of the total NP outputs from the livestock sub-system. The decline in the intensive peri-urban area was due to the decrease in TLU in 2004. There were significant differences between the intensive areas and the other two areas for NP outputs from milk, due to the relatively high milk production of crossbred cows in the intensive areas. The NP outputs from animals sold and died declined significantly in the extensive area, and they increased significantly in the intensive peri-urban area in 2004 due to sale of cattle in this area.

Table 3: Nitrogen (N) flows, farm balance (kg) and CSS soil N balance in four areas of Bhutan (kg yr^{-1} $farm^{-1}$ and kg yr^{-1} ha^{-1}) averages (least square means, lsm) and change from 2000 to 2004 (least square differences 2004-2000, lsd).

Area/ System	Khaling/ Extensive		Dala/ Semi-intensive		Chokhor/ Intensive		Chang/ Int. peri-urban			
Nutrient flows	**lsm**	**lsd**	**lsm**	**lsd**	**lsm**	**lsd**	**lsm**	**lsd**	**s.e[1]**	**s.e[2]**
Farm level inputs										
A[3]. Com. conc.	-	-	-	-	8.3^{b}	2.5	14.1^{a}	-3.1	0.8	1.1
B. Feed ingredients	8.2^{d}	-0.5	21.4^{c}	-0.1	27.3^{b}	1.1	41.9^{a}	-15.3^{z}	1.3	1.8
C. CPR[4] grazing	157.5^{a}	-33.2^{z}	113.5^{b}	-25.5^{z}	115.5^{b}	-2.5	65.7^{c}	-43.0^{z}	5.1	6.9
J. Inorg. fert. to soil	46.0^{c}	18.4	13.8^{d}	27.6^{z}	124.2^{a}	23^{z}	73.5^{b}	-18.2	5.5	7.7
Farm level outputs										
D. Milk	7.8^{c}	0	18.4^{b}	1.8	26.7^{a}	7	27.5^{a}	-8.0	1.0	1.3
E. Animal sold/died	7.1^{b}	-4.4^{z}	7.7^{b}	1.6	8.1^{a}	-1.5^{z}	8.4^{a}	2.5^{z}	0.2	0.2
H. Manure to CPR	59.9^{bc}	-6.1	62.7^{b}	-1.8	96.4^{a}	5.7	47.6^{c}	-23.4	3.0	4.2

L. Crop products	10.1^{c}	3.1	18.2^{c}	4.4	45.1^{a}	10.6	35.5^{b}	-19.1	2.3	3.2
Farm balance	126.9^{a}	-8	41.6^{b}	-3.9	99.1^{a}	2.5	76.2^{a}	-31.5	9.1	13.0
CSS^{5} Level inputs										
I. Manure to soil	56.9^{bc}	-5.8	59.6^{b}	-1.8	91.7^{a}	5.4	45.3^{c}	-22.3	2.9	4.0
J. Inorg. fert. to soil	46.0^{c}	18.4	13.8^{d}	27.6^{z}	124.2^{a}	23^{z}	73.5^{b}	-18.2	5.5	7.7
CSS level outputs										
K. Volatalisation loss	6^{c}	2.4	1.8^{d}	3.6^{z}	16.1^{a}	3^{z}	9.6^{b}	-2.4	0.8	1.1
L. Crop products	10.1^{c}	3.1	18.2^{c}	4.4	45.1^{a}	10.6	35.5^{b}	-19.1	2.3	3.2
O. Crop harvest to soil	4.1^{c}	0.8	5.3^{c}	0.8	12.9^{a}	3.9	9.5^{b}	-4.5	0.5	0.7
P^{6}. CSS to LSS^{7}	48.8^{d}	9.1	100.2^{b}	22.7^{z}	204.9^{a}	23.2^{z}	73.0^{c}	-22.2	1.0	6.5
CSS balance	40^{a}	-0.4	-50.3^{c}	-2.2	-47.1^{c}	-9.2	0.8^{b}	5.4	7.8	9.3
CSS balance/ha	30.8^{a}	-0.3	-19.3^{c}	-0.8	-16.2^{c}	-3.2	0.6^{b}	4.2	6.5	8.1

[a,b,c,d] lsm with different superscripts between study areas are significantly different (p<0.05).
[z] lsd within a study area is significantly different (P<0.05).
[1] s.e of an average between areas, [2]s.e of an average between years within an area.
[3] refers to the flows in Fig. 1; flow R is not in the table, this flow denotes I+J+O-K
[4] common property resources, [5] crop sub-system
[6] includes N flows from crop products, crop residues, fodder trees, conserved fodder and gazing on pasture land

Crop residues were the main NP outputs from the crop sub-system to the livestock sub-system and were significantly highest (Tables 3 and 4) in the intensive area (205 kg N y^{-1} $farm^{-1}$ and 20 kg P y^{-1} $farm^{-1}$). Similarly, NP outputs from crop products were significantly highest in the intensive area (45 kg N y^{-1} $farm^{-1}$ and 23 kg P y^{-1} $farm^{-1}$) since there were a variety of cereal crops grown in this area with significantly higher crop production compared to the other areas.

Table 4: Phosphorus (P) flows, farm balance (kg) and CSS soil N balance in four areas of Bhutan (kg yr^{-1} $farm^{-1}$ and kg yr^{-1} ha^{-1}) averages (least square means, lsm) and change from 2000 to 2004 (least square differences 2004 -2000, lsd).

Area/ System	**Khaling/ Extensive**		**Dala/ Semi-intensive**		**Chokhor/ Intensive**		**Chang/ Int. peri-urban**			
Nutrient flows	**lsm**	**lsd**	**lsm**	**lsd**	**lsm**	**lsd**	**lsm**	**lsd**	**se^{1}**	**se^{2}**
Farm level inputs										
A^{3}. Com.conc.	-	-	-	-	1.7^{b}	0.5	2.8^{a}	-0.6	0.2	0.3
B. Feed ingredients	1.7^{d}	0	4.0^{c}	0.1	5.6^{b}	0.2	9.2^{a}	-3.4^{z}	0.3	0.4
C. CPR^{4} grazing	15.2^{a}	-3.2	10.9^{b}	-2.5^{z}	11.2^{b}	-0.3	6.4^{c}	-4.1^{z}	0.6	0.9
J. Inorg. Fert.to soil	13.1^{b}	1.5	-	-	75^{a}	15^{z}	6.0^{b}	-1.5	2.7	3.6
Farm level outputs										
D. Milk	1.2^{c}	0	2.8^{b}	0.3	4.0^{a}	1	4.1^{a}	-1.2	0.1	0.2
E. Animal sold/died	2.1^{b}	-1.3^{z}	2.2^{b}	0.5	2.4^{b}	-0.4	2.5^{a}	0.7^{z}	0.1	0.1
H. Manure to CPR	6.4^{b}	-0.1	6.9^{b}	-0.2	10.6^{a}	0.9	5.9^{b}	-3.1	0.5	0.7
L. Crop products	7.8^{b}	1.6	13.1^{c}	2.6	23.1^{a}	3.1	8.2^{b}	-2.7	1	1.5
Farm balance	12.5^{b}	-2	-10.1^{d}	-5.6	53.5^{a}	10.9^{z}	3.6^{c}	-3.3	9.1	13
CSS^{5} level inputs										
I. Manure to soil	7.5^{b}	-0.1	8.1^{b}	-0.2	12.3^{a}	1.1	6.9^{b}	-3.6	0.6	0.8
J. Inorg. fert.to soil	13.1^{b}	1.5	-	-	75^{a}	15^{z}	6.0^{b}	-1.5	2.7	3.6
CSS level outputs										
L. Crop products	7.8^{b}	1.6	13.1^{c}	2.6	23.1^{a}	3.1	8.2^{b}	-2.7	1	1.5
O. Crop harvest to soil	1.2^{b}	0.3	1.5^{b}	0.2	4.4^{a}	1.8	1.7^{b}	-0.8	0.2	0.3
P^{6}. CSS to LSS^{7}	3.9^{c}	0.5	5.1^{b}	1.2	19.7^{b}	5.5^{z}	7.3^{a}	-3.3^{z}	1	1.5
CSS balance	7.7^{b}	-1	-11.7^{d}	-4.3	40.2^{a}	5.6^{z}	-4.2^{c}	1.7	7.8	9.3
CSS balance/ha	5.9^{b}	-0.8	-4.5^{c}	-1.6	13.9^{a}	1.9^{z}	-3.2^{c}	1.3	6.5	8.1

[a,b,c,d] lsm with different superscripts between study areas are significantly different (p<0.05).
[z] lsd within a study area is significantly different (P<0.05)
[1] se of an average between areas; [2]se of an average between years within an area.
[3] refers to the flows in Fig. 1; flow R is not in the table, this flow denotes I+J+O-K.
[4] common property resources, [5] crop sub-system
[6] includes P flows from crop products, crop residues, fodder trees, conserved fodder and gazing on pasture land
[7] livestock sub-system

The soil N balances of the crop sub-system were negative in the semi-intensive (-50 kg y^{-1} $farm^{-1}$ or -19 kg y^{-1} ha^{-1}) and intensive (-47 kg y^{-1} $farm^{-1}$ or -16 kg y^{-1} ha^{-1}) areas. This was attributed mainly due to low inorganic fertilizer inputs in the semi-intensive area and the high crop outputs to the livestock sub-system in the intensive area (Table 3). The crop sub-system P balance was significantly highest in the intensive area (40 kg y^{-1} $farm^{-1}$ or 14 kg y^{-1} ha^{-1}) which was attributed to the high usage of single super phosphate (SSP) (Table 4).

The overall farm N balance was positive in all areas. It was significantly higher in the extensive (127 kg y^{-1} $farm^{-1}$ or 98 kg y^{-1} ha^{-1}) and intensive area (99 kg y^{-1} $farm^{-1}$ or 34 kg y^{-1} ha^{-1}) than in the semi-intensive area (42 kg y^{-1} $farm^{-1}$ or 16 kg y^{-1} ha^{-1}). CPR grazing was the main contributor to the positive N balances in the extensive and semi-intensive areas (Table 3). The overall farm P balance was significantly the highest in the intensive area (54 kg y^{-1} $farm^{-1}$ or 18 kg y^{-1} ha^{-1}) in 2004 due to the significant increase in use of SSP. In the semi-intensive area the P balance was negative (-10 kg y^{-1} $farm^{-1}$ or -4 kg y^{-1} ha^{-1}) in 2004 mainly due to a significant decrease in P input from CPR grazing (Table 4).

Discussion

Impact of intensification on CPR use for feeding cattle

In the Himalayan area, the livestock population exceeds the carrying capacity of land resources (ICIMOD 1985). Studies on the livestock carrying capacity and the use of CPR in Bhutan mentioned that that the bulk of the livestock population were underfed and was highly dependent on CPR, and that these CPR were heavily overgrazed (Dorji 1993; Moktan et al 2008). In this study, in all four study sites CPR played a major role in the maintenance of the herds by complementing the limited feed resources produced on the farms, mainly crop residues and by-products, and those bought from the market. However, in the intensive areas with a majority of crossbred animals, the farmers rely much less on CPR than in the other two areas. Farmers with crossbred cattle feed more concentrates and conserved fodder. Nevertheless, in the intensive area about one quarter of the TDN requirements were met by CPR. Without CPR about one quarter less animals can be kept by individual farms in the intensive area, while in the extensive and semi-intensive areas it is about one half less (Figure 4), or more concentrates and on-farm produced animal feed crops are needed. So, though crossbreeding has not resulted in major reductions in cattle numbers per farm, it has contributed to reducing use of CPR by farmers (Tables 2, 3 and 4). The number of farms with crossbred cattle was more or less the same in 2000 and 2004 (Samdup et al 2010). The urban development in the intensive peri-urban area shows that urbanisation had a much bigger impact on herd sizes and on the FFB than crossbreeding and promoting on-farm feed resources. In the intensive peri-urban area in four years' time the average farm area and herd size were reduced by 27% and 49%, respectively.

The comparison of the TDN available and the requirements per TLU for the actual production levels at farm level showed that in 2000, the herd sizes did not match the feed sources; in particular the extensive area had a 26% excess of TLU (Figure 3). In 2004, only the extensive area still had an excess of 15% TLU (Figure 3). The slight reduction in number of local cattle per farm was a reason for this, or it could be that we underestimated the TDN consumed in this area. In the extensive area, Jersey crossbreds had a high mortality of 16%, while in the other areas mortality ranged from 7-9%. The herds in the extensive area were generally weak and the calving rates of local cattle and Jersey crossbreds were all below the calving rates needed to maintain the herds (Samdup et al 2010). This information together with field observations supported the conclusion that there is a feed shortage in this area. This can be addressed by increasing crop production and bringing associated feed residues from outside (equivalent to about 2770 kg TDN per farm per year would be needed) on farm or by reducing the herd sizes. In this area, crushed maize seeds and maize straw is the main crop by-products fed, so cultivation of improved varieties of maize could make more feeds available to some extent. Therefore crossbreeding in extensive areas without adequate access to markets and feed resources is not advisable.

Impact of intensification on farm nutrient (NP) flows

Cattle play an important role as agents of nutrient cycling especially for transfer of biomass from the CPR to the farms. Without CPR grazing there would be a considerable decline in NP flows from the livestock sub-system to the crop sub-system and all four areas would have had highly negative crop sub-system NP balances. Even with CPR grazing the crop sub-system N balance was positive only in the extensive area (31 kg y^{-1} $ha^{-1)}$ (Table 3), while the P balance was positive only in the intensive area (14 kg y^{-1} ha^{-1}) (Table 4). In the intensive areas farmers practise indigenous methods to optimise use of the limited P pools by burning the top soil to increase availability of P, and burning manure to reduce its bulk and speed up release of P (Roder et al 2003). They also used SSP mainly for potatoes which contributed to the positive crop sub-system P balance. Roder et al (2001) and Norbu and Floyd (2004) mention that soils in Bhutan generally exhibit low pH and also low fertility in terms of N due to high soil erosion potential and limited soil depth of organic matter. Farmers normally intuitively decide how much fertilizer to apply which may cause such NP imbalances. More awareness on nutrient management is required among farmers. Nutrient balance studies can help to serve as indictors for the magnitude of losses of nutrients and to identify causes for such losses. The interpretation of nutrient balances can be further improved by linking the farm nutrient budgets with total soil nutrient stocks (Van den Bosch et al 1998), but this was beyond the scope of the present study and more research is required.

Methodology

The period of comparative study in a span of four years (mid of the 9th Five year plan to mid of the 10th Five year plan and change-over in crossbreeding policy) could be argued to be too short to evaluate the impact of the livestock intensification policies, but it does provide a perspective and methodology of such studies which are rare in Bhutan. Although this study was mainly based on field surveys the nutrients contents of plants and animal products were based on available literature. Soil samples could also not be analysed for their N and P content since the facilities were not available. Nevertheless, the results indicate the diversity and resilience of smallholder farm systems and the crucial role of CPR in these systems in Bhutan.

Future developments

Though Bhutan is a small country, the diversity of smallholder farmers livestock rearing and farm management practices indicates that there can be no single recommendation on livestock and farm management practices. Though livestock intensification has not resulted in major reductions in cattle numbers per farm, but it has contributed to reduced use of CPR. Intensification also partly replaces farm nutrient inputs from CPR with nutrient inputs through increased use of concentrates, conserved fodder, and fertilizers. While there is potential for intensification in the intensive areas, such practices may not be feasible in the extensive and semi-intensive areas. Though there is very high demand and good prices for livestock products in the intensive areas, the increasing costs of concentrates and fertilisers could be a major challenge. The current government policies promote local produce and are aimed at reducing imports, via strict financial and monetary regulation for imports. These measures will have an impact mainly in the intensive areas. They should be accompanied with appropriate extension services and market availability. Finally, in the process of livestock intensification, its impact on the quality or conservation of the CPR will also need to be assessed; such studies could also serve as a useful analytical tool for natural resources management planning.

Conclusion

- In Bhutan, dairy crossbreeding has contributed to reducing grazing pressure on CPR in areas where there is accessibility to markets and feed resources. However, even in the intensive area with a high proportion of crossbred cattle, CPR still met about one quarter of the feed requirements. Additional feed can be made available through intensification of crop production and making more crop residues available, and growing fodder trees for livestock feeding. Such interventions could alleviate feed shortages, but may not be able to replace grazing in CPR given the limited farm land sizes and resources. So, CPR will remain an essential feed source, also for farms with crossbred cattle. Grazing in the CPR provided the majority of the N inputs at farm level. If there would be no CPR grazing then farms in all four areas would have negative N balances. More awareness needs to be created among farmers on nutrient management, in particular appropriate use of fertilizers.

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Received 4 March 2013; Accepted 9 May 2013; Published 1 July 2013

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