Gender roles and greenhouse gas emissions in intensified agricultural systems in the mid-hills of Nepal

Working Paper No. 47

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Bishal K. Sitaula
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CCAFS Coordinating Unit - Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark. Tel: +45 35331046; Email: ccafs@life.ku.dk

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Abstract

This paper assesses gender differences in agricultural activities that have a potential effect on N_2O emissions from agricultural soils in the Ansikhola watershed of the mid-hill region of Nepal. Multiple methods were used to collect data, including a questionnaire survey (310 households), six focus group discussions, five key informant interviews and field gas flux measurements over a year. Results indicate that women are involved in farmyard manure (FYM) collection, transport and application. Decisions regarding which crops to plant and about purchases of chemical fertilizers have changed over the last 20 years, with women now being more included in such decisions, although this is happening more among higher and middle caste groups than in the lower castes. Involvement of women in community-based agriculture-related institutions has also increased, regardless of caste. Field flux measurements show variation in N_2O emissions depending on the type of land use (e.g. *Khet* versus *Bari*), cropping system (traditional versus intensified) and across seasons (e.g. higher during the rainy season). The results show that increased fertilizer application over 20 years has resulted in a higher intrinsic propensity of the soils to emit N_2O. Therefore the ongoing intensification of agriculture in South Asia may result in increasing N_2O emissions.

Keywords

Keywords: gender; Nepal; agricultural intensification; mitigation; manure; fertilizer; N_2O emissions.

About the authors

Nani Raut received her PhD from the Department of International Environment and Development Studies, Norwegian University of Life Sciences, UMB, Norway. (nani.raut@umb.no)

Bhola Raya is a Master's degree student at the Department of International Environment and Development Studies, Norwegian University of Life Sciences, UMB, Norway.

Bishal K. Sitaula is a Professor at the Department of International Environment and Development Studies, Norwegian University of Life Sciences, UMB, Norway.

Roshan M. Bajracharya is a Professor with the Department of Environment Science and Engineering, Kathmandu University, Dhulikhel, Nepal.

Patti Kristjanson is an agricultural economist and research leader of CCAFS, based at the World Agroforestry Centre in Nairobi (p.kristjanson@cgiar.org).

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List of abbreviations

APP	Agriculture Perspective Plan
CEAPRED	Centre for Environmental and Agricultural Policy Research, Extension and Development
CIP	Country Investment Plan
DADO	District Agriculture Development Office
DAP	Diammonium Phosphate
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
FYM	Farmyard Manure
IPM	Integrated Pest Management
JICA	Japan International Cooperation Agency
NGO	Non-Governmental Organization
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee

Introduction

In Nepal, the majority of households own less than 0.5 ha. Average household farm size has decreased over the last few decades, mainly due to the tradition of paternal property subdivision among household heirs, as well as a gradually growing population (CIP, 2010; Thapa & Niroula, 2008). Such a trend has seriously threatened the livelihoods and food security of those who depend on agriculture (Thapa & Niroula, 2008). The situation is even worse in the mid-hills region, where landholdings of farmers are already small and the opportunities for them to have other sources of income from non-agricultural activities are limited. Therefore, a majority of the Nepalese hill farmers living near urban centres have been intensifying their cropping systems by increasing from two to three crops per season (Dahal et al., 2009). This has involved an increased use of chemical fertilizers and pesticides, and new production of off-season vegetables and food crops.

Although rural women and men play complementary roles in guaranteeing food security, women tend to play a greater role in natural resource management and ensuring nutrition (FAO, 2000). Women in Nepal live in a society with cultural norms that favour men. Women have lower literacy rates, less access to political power, and as the primary collectors of food, water and fuel wood, are in a more vulnerable position than men to economic, social and environmental changes, including a changing climate. Thus it is imperative that gender policies be integrated into the official discourse surrounding climate policy.

Nepal already has a considerable stake in international accords related to climate change. It has ratified the Rio conventions and prepared the national communication strategy for the UNFCCC (United Nations Framework Convention on Climate Change). It is also a party to the Kyoto Protocol. However Nepal's own policy documents make little mention of climate change. There has been little or no research that attempts to measure greenhouse gas emissions from an agricultural sector that has been undergoing widespread intensification. It is important that this is investigated, as a study of greenhouse gas fluxes under conditions of agricultural intensification will lead to a better understanding of the implications of different agricultural practices for potential actions that can help mitigate impacts of climate change.

The objectives of the study were: 1) to examine gender differences in agricultural activities that have a potential effect on N_2O emissions in the mid-hills of Nepal, and 2) to determine the levels of N_2O emissions from different crops grown under various conditions in intensively cultivated systems. For objective one, the research question was, "What are the gender differences in agricultural-related activities (choices of crops, inputs, trainings and groups)?" For objective two, the targeted research question was, "What is the level of N_2O emissions under different management practices and land uses?" Both quantitative and qualitative methods were used to address these questions.

Background

Gender refers to qualities or characteristics that society ascribes to each sex by which women and men are identified (Jagerskog & Clausen, 2012:25). Although rural women and men play complementary roles in guaranteeing food security, women tend to play a greater role in maintaining the household, ensuring nutrition and natural resource management. The commercialization of agriculture in developing countries has led to production and consumption changes for men and women. Researchers have studied gender-based agricultural division of labour and its implications in many developing countries (Buviniv & Mehra, 1990). They find that women's work in rural areas is strenuous and time consuming. Besides many farm activities, women are also responsible for household chores. In Asia, between 50 and 90 per cent of the work in rice fields is done by women (FAO, 2002). And after harvest, rural women are almost entirely responsible for storage, handling, stocking and processing. Understanding the local gender division of responsibilities, work and knowledge is key where improvements in natural resource management and well-being are sought (Meinzen-Dick et al., 2010).

Agriculture, the mainstay of Nepalese economy provides about one-third of GDP, employs two-thirds of the country's labour force, and is central to rural livelihoods (Gauchan, 2008). With a view to launching the agricultural sector program of Nepal, the Agricultural Prospective Plan was developed in 1995. The Agriculture Perspective Plan (APP) has also prioritized addressing of gender issues and recognized it as one of the important implementation strategies. One of the major components of the Country Investment Plan (CIP) is gender inclusion, the objective of which is to bring women into the mainstream of agricultural growth through skill development training, participatory research and participatory development related activities (CIP, 2010). Specifically, the CIP aims to improve women's access to production inputs and credit, and bring them actively into income generation and marketing activities.

One of ten priority areas mentioned in the Eighth Plan is agricultural intensification and diversification. Associated with the Eighth Plan is the government's policy of incorporating women into the economic development of the nation. Strategies to ensure women's participation in commercial agricultural activities include the expansion of women's access to formal and informal education, increased access to credit, technological knowledge, market facilities and employment opportunities.

The APP has a strategy for hill and mountain areas that includes approaches aimed at increasing production of high-value crops and livestock products. It recognized that a subsistence-based traditional farming system (Rasul & Thapa, 2003) has been unable to support a growing population and their subsistence needs, and thus a shift towards crop intensification was needed (Paudel & Thapa, 2004; Brown & Kennedy, 2005; Tiwari et al., 2008). The traditional farming system, characterized by low fertilizer levels and one or two crops per year, is replaced by a system that uses more fertilizer and produces a minimum of three crops per year. For purposes of this analysis, 'intensified' agriculture refers to three crops being planted per year that uses more fertilizer. In recent years, cash crops – including vegetables, which demand high doses of chemical fertilizers – have gained importance in mid-hill regions.

The environmental implications of increased chemical fertilizer use are poorly addressed in scientific and policy arenas of Nepal. There is evidence to suggest, however, that one of the consequences of such intensification is that the soil pH is lowered, and decreased pH leads to denitrification that liberates more N_2O gas in the environment (Guo et al., 2010; Simek & Cooper, 2002). N_2O, a potent greenhouse gas (Forster et al., 2007), is a stratospheric ozone depleting substance (Ravishankara et al., 2009) and has 296 times stronger specific global warming potential than an equal mass of CO_2. Agricultural soils account for a large proportion (70-81 per cent) of the increase in N_2O emissions to the atmosphere with the increase linked to measured N fertilizer use (Barton et al., 2008). Soil microbial activity is the major source of atmospheric N_2O (Barton et al., 2008), primarily through denitrification, which refers to the reduction of nitrate or nitrite to gaseous products, that is, NO, N_2O and N_2. This study contributes to a better understanding of the environmental consequences of highly intensive cropping systems and activities by measuring N_2O emissions from agricultural soils under different conditions and cropping seasons.

Methodology

Both quantitative and qualitative methods were used and are described below. Preliminary field visits were made in order to understand field conditions and select experimental plots for the field flux measurement. Greenhouse gas (N_2O) emissions from the soil were analyzed in the laboratory. Household-level surveys, group discussions and key informant interviews were conducted.

Study area

The study area comprises the Ansikhola sub watershed, located in Kavre district of Nepal (Figure 1). The sub watershed lies between latitudes N 27°41' and 27°44', and longitudes E 85°31' and 85°37'30" and extends over an area of 13 square km. The elevation of the watershed ranges from 800 m at the bottom to 2000 m on the hill slopes. The climate is warm sub tropical with annual rainfall of 1389 mm.

The annual maximum and minimum temperatures in the area are 25°C and 17°C respectively, with an annual relative humidity of 74 per cent (Dahal et al., 2007). The cultivated areas consist of *Bari* and *Khet* land. *Bari* lands are of two types: 1) *Gharbari* (land around the homestead) and 2) *Pakhobari* (less productive separate plots, usually away from the homestead). *Khet* lands are also of two types: 1) *Galkhet* (levelled terraces with irrigation) and 2) *Tarkhet* (levelled terraces that are not irrigated and so depend on monsoon rain).

The reasons for choosing the Ansikhola watershed for this study were: 1) it is representative of mid-hill watersheds located in relatively close proximity to urban centres; because of these expanding urban markets, farmers have been intensifying their cropping systems (i.e., shifting to three crops per annum with high fertilizer inputs) in recent years; 2) the site represents a heterogeneous socio-economic situation and different caste groups involved in agriculture; 3) research into the implications of agricultural intensification on soils, water and pesticides has been carried out in the same watershed, which helped in building trust and relationships for this work. The watershed area has four village development committees (VDCs) made up of a total of 12 wards (the sub-unit of a VDC), encompassing a total of 1038 households.

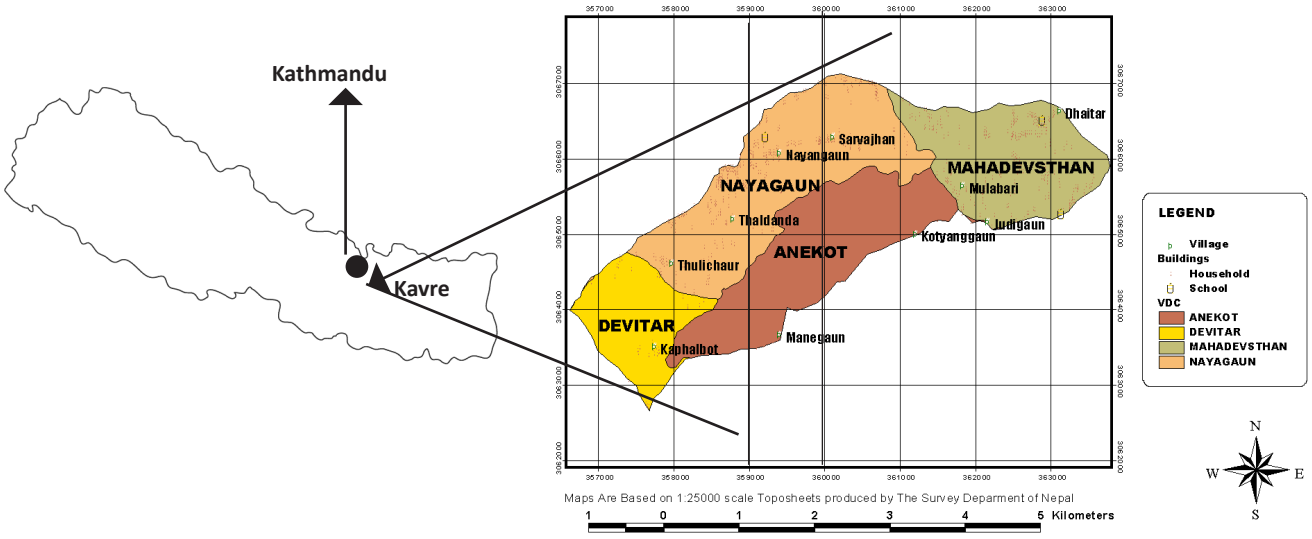

Figure 1. Location of the study area (Ansikhola watershed)

Table 1. Major cropping patterns in the Ansikhola watershed (Raut et al., 2011a)

Cultivated land types	Cropping pattern (3 crops)	Cropping pattern (2 crops)
Khet	Rice-potato-rice	Rice-rice
	Rice-potato-maize/Rice-maize-rice	Rice-maize
	Rice-potato-maize	Rice-maize
	Rice-potato-vegetables	
	Rice-potato-tomato	
Bari	Vegetable-maize-potato/Maize-mustard-potato	Maize-potato
	Chilly-vegetable-potato	Maize-millet
		Maize-millet/Maize-wheat

Data collection methods

Data collection was conducted through household surveys, focus group discussions (FGDs), key informant interviews and direct observation. The survey was conducted in 310 households. These households were the same ones that had been selected for the survey in 2009 using a random sampling procedure (Raut et al., 2011) to collect information on the trends of agricultural intensification such as status of landholdings, trends of fertilizer use, cropping patterns, irrigation facilities, labour investment priorities, livestock holdings, and the status of institutional support services in agriculture. A structured questionnaire that included both closed and open-ended questions was implemented. The survey was conducted between March and April in 2012 by three trained enumerators. In a Nepalese context, the head of the household is usually the decision-maker. Thus, the heads of selected households were interviewed using the structured questionnaire in order to obtain demographic information and information on involvement of labour on fertilizer and pesticide application.

Separate focus group discussions (FGDs) were conducted with different caste groups. Each group consisted of seven to ten people. According to the Nepalese legal code of 1854 (Dahal et al., 2009), the castes in the watershed include a high caste made up of Brahmin and Chhetri groups, a middle caste that includes Gurung, Tamang, Rai and Newars, and a low caste group that includes Damai (tailors and drummers), Kami (blacksmith) and Sarki (leather workers). The list of households in the watershed was first divided into three groups based on the castes. For each group, random sampling was used to select participants for the FGD. In each caste group, one FGD for women and one FGD for men were conducted. The FGD was conducted separately for men and women since some of the women had mentioned that they could only engage in open discussions in the absence of men. A total of six FGDs were conducted, three with each gender. The size of the groups was between 7 and 11 respondents. The purpose of gathering was explained briefly, and a semi-structured discussion lasting two to three hours followed. The groups discussed gender roles in different agricultural activities including choice of crops, fertilizer application and land preparation. Each group also discussed the involvement of men and women in community-based local institutions such as forest users' groups, and savings and credit cooperatives.

The selection of key informant interviews was also done randomly. A total of five key informant interviews were undertaken. Two female key informants were selected from female-headed households, as well as two male key informants from male-headed households. A farmer who is a member of a local cooperative group was also chosen as a key informant. The purpose of separate interviews with men- and women-headed households was to assess gendered labour implications of agricultural activities. Direct field observations were also made.

Gas flux measurement

Gas flux samplings were carried out for both land uses: *Bari* (drained, non-terraced) and *Khet* (flooded, terraced). For each land use, two treatments were selected: 1) a traditional agricultural system with two crops per annum, and 2) an intensified agricultural system with three crops per year. The sampling was done at an interval of 7 to 15 days over a period of one year between May 2009 and April 2010. The gas fluxes were measured using a closed chamber technique with four replicates for each treatment in each land use. The chamber has a 220 mm internal diameter and 250 mm height, with a 20 mm cutting edge. One 12 mm diameter hole was drilled at the bottom of each chamber and was capped by a butyl rubber stopper, for transferring gas into 10 mL and evacuated up to 10^{-1} Kpa before the gas samples were transferred. Gas samples inside the chamber were taken by piercing a two-way syringe through the rubber stopper. Soil temperature and moisture were also measured during each time flux measurement because high soil temperature and moisture condition are likely to increase N_2O emission. N_2O concentrations were measured in the laboratory using Gas Chromatography.

Data analysis

The information obtained from the focus group discussions and key informant interviews was qualitatively analyzed and descriptive statistics used to analyze the quantitative data.

The linear mixed model used for the analysis of field flux data is as follows:

$$Y = X\beta + Zu + \varepsilon$$

$$u \sim N(0, V(\gamma))$$

$$\varepsilon \sim N(0, V(\delta))$$

where: Y is the response vector for observations, X is the model matrix for the fixed effects for observations, β is the vector of fixed-effect coefficients, Zi is the model matrix for the random effects for observations, u is the vector of random-effect coefficients, and ε is the vector of errors for observations.

Fixed effects are those variables directly recorded in the course of the experiment. When the number of observations per cluster is large, we treat them as fixed effects. Fixed effects are related to a trend in the data set. They are widely used in analysis of biological or experimental data, such as in the case of moisture and temperature effects. Random effects are treated as if randomly sampled from a large population and are non-specific/unknown effects, also referred to as pseudo-replication. The error term is a residual and relates to correlation and variance in the data at the smallest group level.

The objective of the research was to estimate how N_2O gas emission are affected by different land use types, different seasons and treatments. Two types of land-use were chosen, non-terraced farmland and terraced farmland, with two types of treatments each: traditional versus intensified (two cropping seasons or three cropping seasons annually).

Results and discussions

Demographic characteristics

The majority of respondents studied belong to the middle caste (50 per cent), followed by high caste people (45 per cent). The predominant religion is Hindu (Table 2). Almost half of respondents are illiterate and agriculture is their main occupation (90 per cent).

Table 2. Demographic characteristics of the watershed

Caste system					
Percentage of respondents	High caste	Middle caste		Low caste	
	45	50		5	
Religion					
Percentage of respondents	Hindu		Buddhist		
	73		27		
Education					
Percentage of respondents	Illiterate	Primary	Secondary	Higher Secondary	University
	49	24	1	2	2
Occupation					
Percentage of respondents	Agriculture	Business	Service	Student	
	90	1	7	2	

Gender and caste-specific division of labour in land preparation

Both men and women actively participate in land preparation activities. The first phase of land preparation involves cutting and removal of vegetation and incorporation of crop residues. This step is mostly performed by women. Table 3 shows gendered differences in agricultural activities including land tilling, fertilizer application, pesticide application and irrigation among different caste groups. The group discussions revealed that ploughing is currently performed only by men. It is mostly women who break up the soil clods after ploughing is done, although in a few cases, women also ploughed using a hand hoe. The gender-based division of labour here is similar among all three caste groups. In the past, ploughing was done only by low caste people. Since land has become scarce and farmers have gradually been intensifying, men from high caste are also involved in ploughing. One of the key informants mentioned that low caste farmers are also intensifying (i.e. applying more inputs than previously), resulting in labour shortages, thus forcing high caste farmers to do their own ploughing. A study by Tiwari et al. (2008) found that low caste people gained more from commercial vegetable production, and therefore stopped ploughing the land of high caste people for relatively low returns. Before intensification was adopted in the study area, ploughing was carried out using oxen and hand hoes (known as *kodali* in the local language). Up to the 1990s, few farmers hired hand tractors for use during ploughing seasons from nearby villages. Recently, it was recorded that four farmers own hand tractors in the watershed (Raut et al., 2011). These are mostly used to plough flat lowlands. Some of the farmers who own hand tractors also hire them out to earn additional income. During cultivation season, hand tractors are operated for up to 15 hours in three different shifts (Raut et al., 2011).

Table 3. Gender-based labour use for different agricultural activities

Agricultural activities	Higher caste
Tillage	
Plough	♂
Breaking clods	♀
Fertilizer	
Carrying farm yard manure (FYM) to field	Mostly ♀
FYM Spreading	Mostly ♀
Decision on buying chemical fertilizers	Both
Application of chemical fertilizer in field	Both
Pesticides	
Pesticide buying	Mostly ♂
Pesticide spraying	Mostly ♂
Irrigation	
	Mostly ♂
Choice of crop	**Both**
Agricultural training	IPM ♀ Distance training ♂

Gendered consequences of fertilizer application

Green tree leaves, grass and crop residues such as wheat straw are used to feed animals or used as bedding in the animal shed. The animal sheds are cleaned everyday of cattle dung, urine and uneaten forage, which is stacked in a heap. Once the heap turns dark brown or black, it is referred to as farmyard manure (FYM). FYM is carried to the fields by women, regardless of caste. The manure is also spread by the women. This finding is consistent with another study by Pilbeam et al. (2005), who found that FYM is transported mainly by women in bamboo baskets, and spread prior to ploughing. The most common reason given by women during key informant interviews and group discussions on why they are predominantly involved in FYM, was that they are the ones who clean the cattle sheds everyday and spend more time on household activities than men. Most men agreed. One respondent noted, "*Women are more experienced at knowing whether the FYM heap is ready for use in the field*." The trend of FYM use was found to be decreasing between 1989 and 2009, and there existed a positive strong correlation between FYM application and livestock numbers, which indicates that the extent of FYM use is determined by the number of livestock per household (Raut et al., 2011). One of the respondents during group discussion of the lower caste mentioned, "*When we began growing commercial vegetables, we started keeping cows or goats so that our children could have milk and at the same time get FYM for the crops*." However, livestock numbers have decreased during the same period in this watershed. This is apparently because farmers have concentrated more on milk production than on manure production, and prefer to keep smaller numbers of pure or cross-bred varieties of cattle, rather than keeping large numbers of indigenous/local cattle breeds, thus leading to a decrease in the number of livestock. In addition, farmers prefer to use FYM for higher value crops, such as winter potatoes, rather than for other crops. A study by Westarp et al. (2004) also found this to be true. The reason for applying FYM to higher value crops is that there is a higher residual efficacy of manure applied to winter crops over summer/rainy crops.

Farmers in the Ansikhola watershed have increased their chemical fertilizer applications with the shift to three crops per year. The major chemical fertilizers used in the area are urea and diammonium phosphate (DAP). Household-level decision-making is changing to a more inclusive

and consensus-based approach with more family members involved than before. Discussants from high and middle caste groups indicated that both men and women are now involved in making decisions on the purchase of chemical fertilizers. However, in the lower caste groups, such decisions are being made only by men.

The decision-making process regarding purchase of chemical fertilizers has also changed with the introduction of commercial vegetable farming in the mid-hill region. A shift from a traditional, 2-season cropping system to a more intensified, 3-season annual cropping season has contributed to a change in the division of labour between men and women. In the past, men made the decisions regarding purchase of chemical fertilizers, while nowadays, women are also involved together with their husbands. Since high and middle caste farmers have greater landholdings than low caste farmers, the adoption of agricultural intensification practices has led to a much higher demand for agricultural labour. One of the consequences has been a higher involvement of high caste female farmers in applying chemical fertilizers to crops. The total labour time (including men and women) involved in fertilizer application is higher within the *Galkhet* followed by *Tarkhet*. The least labour time use was in *Pakhobari* (Table 4). From 1999 to 2009, *Galkhet* received significantly higher amounts of urea and FYM as compared to other land-use types (Raut et al., 2011).

Table 4. Labour use in fertilizer application

Manure	N (Number of respondents)	Mean number of hours/ year/ha)
Galkhet	295	249
Tarkhet	306	168
Gharbari	305	119
Pakhobari	287	87

Gender and use of pesticides

The results indicate that it is men who make the decisions about and buy pesticides in all castes. The most common reason given for this was that men spend significantly more time in activities away from the household and they had more experience with cash transactions. However, it turns out that pesticide application is carried out by both men and women, according to both groups (women do it when men are too busy). However, both groups argued that it was not good for pregnant women and children to be engaged in such activities, as pesticide application causes health problems such as headaches, skin and eye irritations. Other studies (Azaroff & Neas, 1999; Garcia, 2003) also showed that women experience a significantly increased risk of health and well-being issues when applying pesticides. Some men argued that they try to minimize the involvement of women and children since a lot of physical strength is required to carry a heavy pesticide sprayer during application. A study by Atreya (2007) in the mid-hills region asserts that men are better educated and thus make the decisions on pesticide application, and are more aware of, and understand the labels better than women. The labour time use on pesticide application was higher for *Galkhet* than other land-use types (Table 5). This was also found in another study (Raut et al., 2011). According to this, the most significant change in cropping patterns in the shift from two to three crops is in *Galkhet* lies in the introduction of potatoes, vegetables and spring rice paddy crops.

Table 5. Labour use in pesticide application

Agricultural land-use types	N (number of respondents)	Mean number of hours/year/ha
Galkhet	295	177
Tarkhet	306	101
Gharbari	305	59
Pakhobari	287	0

Agricultural training and gender differences

Farmers in the study had participated in integrated pest management (IPM) training, as well as in commercial off-season vegetable production, and some farmers had also participated in exposure trips and observation visits to farmers' field schools and commercial farm stations in other parts of the country, organized by the District Agriculture Development Office (DADO) and by non-governmental organizations (NGOs) such as the Japan International Cooperation Agency (JICA) and the Centre for Environmental and Agricultural Policy Research, Extension and Development (CEAPRED) (Raut & Sitaula, 2012). This raised confidence levels and enhanced technical skills among many. The women's focus group discussions pointed out that women were more involved in integrated pest management (IPM) training sessions, whereas men were more involved when farmers had to be away from home, such as exposure trips. Women also argued that it was not good for them to participate in trainings where they had to be away from home because they had to take care of the children and the rest of the family members. However, women farmers acknowledged that trainings on cash cropping in the past had helped them to be a part of decision-making activities and had led them to play a more active role in society.

The participants of lower caste groups argued that they had not participated in any agricultural-related training. One of the lower caste women mentioned that, "*Normally such trainings were communicated to key persons (coming) from a higher caste and (he) only invited people in his network and therefore we never got (a) chance.*" Some men from the higher caste mentioned that lower caste people had other occupations as a their major source of livelihood, plus they had smaller landholdings as compared to higher and medium caste farmers, which overshadowed their participation in agricultural trainings. They also mentioned that even when informed, the lower caste people did not show interest in participation, contradicting the explanation from lower caste respondents of never being informed. Some female discussants showed a common interest in participating in training on fertilizer application so that they could better judge the amount of both chemical and organic fertilizer needed and applied. Women farmers from higher and medium castes argued that it was mostly women who decided on the choice of crops, whereas men believed both decided. The case for lower caste people was different, suggesting that this decision was made mainly by men. Another study showed a process of change in household-level decision-making, particularly regarding crop selection and farm inputs (Tiwari et al., 2008), which contradict the findings of our study as pertains to lower caste people.

Gendered involvement in community-based local institutions

After the adoption of intensified cultivation practices, community-based activities involving local level groups/institutions have gained momentum in the study area. In the FGDs and key informant interviews, farmers reported that there are many local level institutions established in the watershed playing some kind of supportive role, mostly in the adoption of crop intensification and commercial vegetable farming, but not necessarily only agricultural-related. These institutions are listed in Table 6. Three of the community-based local institutions in the watershed consist only of women. The rest of the groups have both women and men members. Female-based local institutions were mainly involved in microfinance and savings efforts. As one of the key informants explained, "*Women are more concerned about sending their children to boarding schools and securing funds for their future*."

Table 6. Gender involvement in community-based local institutions in Ansikhola watershed

Local institutions	Involvement
Panchakanya Cooperative	Mostly ♀
Forest User Groups	Mostly ♂
Samjhana Cooperative	Only ♀
Mothers' Group	Only ♀
Laxmi Cooperative	Only ♀
Societal Development Fund (Samudayek Bikash Kosh)	Both
Cooperative for Milk Collection	Mostly ♂
Saving and Credit Cooperative	Both

Seasonal variation of N_2O emissions

Seasonal variation of nitrous oxide (N_2O) emissions (g N_2O m^{-2} per season) in two different land uses and two different treatments are shown in Figures 2 and 3.

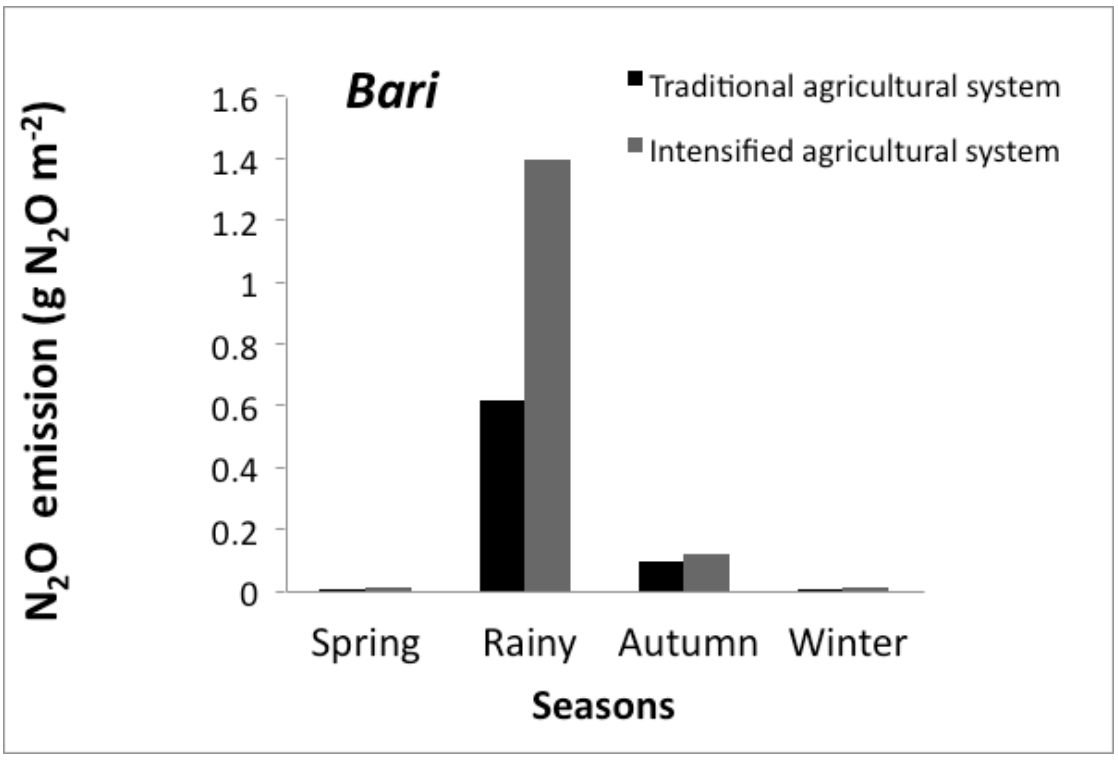

Figure 2. Seasonal variation of N_2O emission in *Bari* land

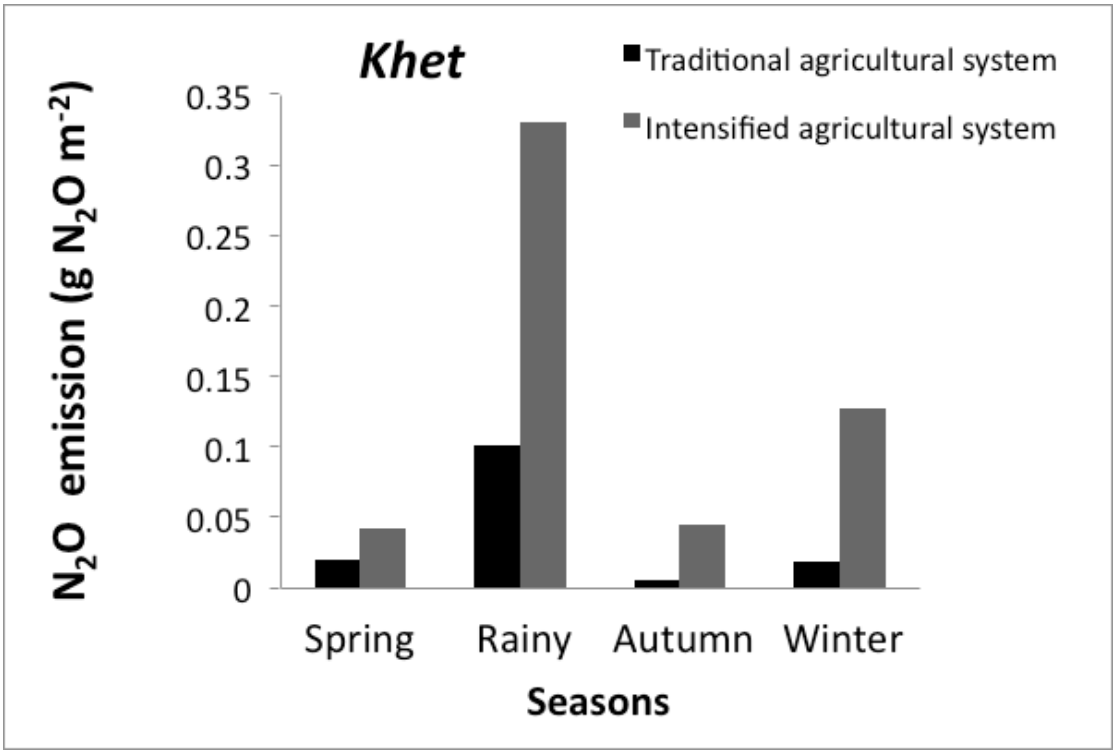

Figure 3. Seasonal variation of N_2O emission in *Khet* land

Throughout the tracking period, emissions were higher during the rainy season compared to other seasons, and were significantly higher in the intensified agricultural systems (three cropping seasons) for both the flooded and drained farmland. The seasonal accumulated fluxes of N_2O emission during rainy season were > three times in intensified flooded farmland and > two times in drained farmland as compared to respective traditional farmland. The accumulated N_2O emission for the whole year was four times higher in intensified flooded (5.4 kg N_2O ha^{-1}) compared to traditional flooded farmland. Likewise, the accumulated N_2O emission for the whole year was two times higher in intensified drained (15.4 kg N_2O ha^{-1}) compared to traditional drained farmland. The results show that the interaction effect of land use, treatment and season on N_2O emission was significant (p<0.01). Table 7 shows the estimates for each combination of land use and treatment with corresponding standard errors.

The results showing that N_2O emissions are higher during the rainy season compared to other seasons in both land uses and treatment are not surprising. The rate of N_2O production is regulated by moisture content in the soil (Lemke et al., 1998; Rafique et al., 2011). The high moisture content creates anaerobic sites in the soil pore volume. This condition is favorable for incomplete conversion of nitrate (NO_3) to dinitrogen (N_2) known as denitrification, leading to release of N_2O as a byproduct. Although *Bari* soils are drained soils, during the rainy season they get saturated, whereas *Khet* soils are flooded as needed by the rice crop. The major crops during the rainy season in *Khet* and *Bari* lands are rice and maize. Rice needs irrigation frequently. However, N_2O emission from *Khet* soils was lower compared to *Bari* soil. This might be because *Khet* soils are exposed to flooding for prolonged periods, microbial community is more tolerant to such conditions. It is also likely that due to periodic flooding, the diffusion of N_2O from the soil to the atmosphere gets interrupted. Thus the microorganisms behave normally and produce less N_2O as compared to what they produce in *Bari* soils. There are different denitrifying enzymes that carry out the complete denitrification process converting NO_3 in the soil to N_2 to the atmosphere. One of the important enzymes in the process is N_2O reductase (that reduces N_2O to N_2), the last part of the process of denitrification, which is affected by moisture during rainy seasons. This then leads to incomplete denitrification with higher emission of N_2O. With increasing crops per annum, significantly higher input of nitrogen fertilizer in the three cropping system could be a potential site for huge N_2O emission to the atmosphere.

Table 7. Estimated mean and confidence interval

Interaction of land use, treatment and seasons	Estimated mean (μg N_2O m^{-2} h^{-1})	Standard error
Bari-Traditional-Autumn	36.46	0.458
Bari-Traditional-Rainy	164.55	0.390
Bari-Traditional-Spring	4.27	0.748
Bari-Traditional-Winter	2.55	0.579
Bari-Intensified-Autumn	43.63	0.458
Bari-Intensified-Rainy	308.15	0.390
Bari-Intensified-Spring	16.19	0.748
Bari-Intensified-Winter	4.82	0.579
Khet-Traditional-Autumn	2.20	0.458
Khet-Traditional-Rainy	51.07	0.390
Khet-Traditional-Spring	15.89	0.748
Khet-Traditional-Winter	5.74	0.579
Khet-Intensified-Autumn	10.01	0.458
Khet-Intensified-Rainy	184.09	0.390
Khet-Intensified-Spring	28.21	0.748
Khet-Intensified-Winter	32.82	0.579

Conclusion

The study shows that ongoing agricultural intensification in Nepal is changing the roles of men and women with respect to various agricultural activities that could have an impact on greenhouse gas emissions. Men are doing most of the ploughing, and women then further break up the soil clods. The involvement of women in savings and credit cooperatives has increased regardless of caste. Women gather, transport and apply farmyard manure. Women are increasingly becoming involved in decisions jointly with their husbands regarding chemical fertilizer use and purchase, and choice of crops, although this is happening more for women among higher and middle castes than lower castes. The increased use of fertilizer associated with an increasing number of crops per annum has accelerated emissions during the water-saturated and flooded periods. The analysis suggests that increased fertilizer application has resulted in a higher intrinsic propensity of the soils to emit N_2O. These increases in N_2O emissions could contribute further to climate change unless addressed through mitigation-focused efforts and initiatives aimed at improved management (e.g. more targeted application) of chemical fertilizers. Since women are increasingly involved in FYM and chemical fertilizer application, their roles are important in nitrogen management in the agricultural lands. With Nepalese women becoming increasingly involved in agricultural practices that can have negative environmental impacts, more thinking needs to go into how best to target improved information and interventions towards women in order to improve environmental sustainability of ongoing intensification.

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