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Eco-balance analysis of land use combinations to minimize environmental impacts and maximize farm income in northern Japan

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Abstract

Relationships between global warming potential (GWP), farmland surplus nitrogen (FSN) and income for major land uses in Ikushunbetsu watershed were compared using the eco-balance method. An empirical model was created for carbon dioxide, methane and nitrous oxide for both uplands and paddy rice using monitoring data from 22 fields. The greenhouse gas emissions were converted into GWP, whereas yield and FSN were obtained from farmers' interviews and literature survey. Land use distribution was obtained by ground survey in 2002, 2005 and 2007. The analysis showed that paddy rice and soybean were characterized by high GWP, low FSN and high income, whereas onion and vegetables had high FSN but low GWP and moderate income. Wheat showed negative

GWP in some years and abandoned area always exhibit negative values. The total GWP for the region was 14184, 11085 and 8337 Mg CO_2 yr^{-1} for 2002, 2005 and 2007, respectively. The contribution of paddy rice to GWP was highest, ranging from 40% to 75%. To find optimal land use combinations that have higher income and lower GWP and FSN than present, all possible land use combination was analyzed by changing the land use proportion from 0 -100% at an interval of 10%. The number of land use combinations meeting the requirements in the three investigated years was 205. Abandoned area which had the smallest environmental load was included in every land use combination, indicating that land uses with low environmental impacts should be maintained at a certain proportion to mitigate the environmental load accompanying land uses with high production.

Keywords

Eco-balance, farmland soil, farmland surplus nitrogen, global warming potential, land use

Introduction

Based on the consensus definition of “sustainable growth” (World Commission on Environment and Development 1987), analysis of production systems has been conducted to achieve the highest productivity with the least environmental loads. Analysis method such as life cycle assessment (ISO 14000 Information Centre 2002) is a strong tool for this purpose. In agricultural production on farmland, the relation of productivity and environmental load must also be analyzed comprehensive and quantitatively to provide a criteria for choosing the most environmentally-friendly management method to farmers and policy makers. However, quantification of nutrient flow in agroecosystem is difficult due to the diverse environmental condition ruling the agricultural production. Characteristics of soil influence the nutrient leaching rate or green house gas fluxes (Gu et al. 2007, Tan et al. 2009). Climate condition changes among years, and a dry and hot year has different environmental concerns than a wet and cold year due to different soil organic matter mineralization rate (Franzluebbers et al. 2001) or susceptibility of applied nitrogen (N) fertilizer to ammonia evaporation (Sutton et al. 2000). In addition, recent environmental loads concerning nutrient cycle, such as global climate change, acid deposition or eutrophication are found not only at the local source area where the pollutant is emitted, but regionally and even globally. The flow of pollutants must be quantified and evaluated at a regional to global scale.

Since most researches on nutrient flow in agroecosystems are conducted at field scale, monitoring data at the fields must be scaled up to regional scale. The up-scaling of monitoring data can be described in several steps (Kimura et al. 2009). The first step is the parameterization of the data monitoring; in which the data are explained by environmental factors. The second step is to get information about the spatial variability. At this step, parameters able to reflect the spatial variation of the target scale must be drawn to a GIS map. The third step is the quantification of the flow and its validation and uncertainty analysis. The final step is the evaluation of the estimated flows and its optimization and mitigation of environmental load.

The challenge of the parameterization is to cover additional information or relationship by more easily obtained data at a larger scale than the monitoring is conducted (Seyfried 2003). At the second step, the accuracy is important. If the gained parameters are of reduced accuracy, the estimated result has also reduced the accuracy. In most fundamental sense, the loss of accuracy with up-scaling is due to the error caused in reflecting the spatial variability. The validation of the estimation is difficult, and sometimes impossible to verify the results. Several methods have been suggested such as verification of the most important process in the extrapolation mechanism (Wagenet 1998) or verification of the N budget with particular attention to water quality (Randall and Gross 2001) The final most important step is the evaluation of the results to show optimization measures. Kimura and Hatano (2007) have proposed an evaluation method, which compare the environmental load to the productivity to analyze the relation of them. The method is defined as eco-balance analysis.

In this study, an eco-balance analysis was conducted using monitoring results of green house gas emissions (GHG) from different land uses and farmland surplus nitrogen (FSN) survey conducted in a watershed scale. Green house gas emissions were parameterized and an empirical regional scale model for nitrogen and carbon flow was created (Kimura et al. 2007). Management methods and productivity were obtained by farmer’s inquiry. The objective of this study was to conduct a quantitative analysis of the relation of GHG emission and FSN to the economic benefit of the land use for the year 2002, 2005 and 2007. Optimal land use combination throughout the years can be suggested based on the analysis.

Study site

This study area was Ikushunbetsu River watershed in the central part of Hokkaido 42 km north west from Sapporo (N 43°14’, E 141°.57’ at the middle of the basin; Figure 1). The Ikushunbetsu River watershed covers an area of 35,887ha and represents a branch of the Ishikari River. The 30-year average annual temperature was 7.4°C, and the annual precipitation 1154mm (Sapporo Distinct Meteorological Observatory 2008). Crop growing was possible after the snow-melt in April until snow-fall in the middle of November. The total area of artificial land uses in the basin since 1905 was 3442 ha. The main agricultural land uses are paddy rice, onion, wheat and grassland. Vegetables such as tomato and cucumber, and soybean represented minor crops. The soils of the area are mostly Fluvisols near the river and Cambisols at higher elevations (Hokkaido Central Agricultural Experiment Station 1971).

Methods

Greenhouse gas fluxes were measured in 22 fields comprising 11 land use types using closed chamber method over a period of 13 years from 1995 to 2008. Carbon dioxide (CO_2) flux from soil organic carbon (C) decomposition was measured on bare soil, nitrous oxide (N_2O) and methane (CH_4) fluxes were measured on planted soils (for detail see Kusa et al. 2002, Naser et al. 2007, Toma et al. 2007, Mu et al. 2008a, 2008b). Annual cumulative flux of each gas was parameterized using soil, climate and management parameters. The GHGs were converted into GWP (Intergovernmental Panel on Climate Change 2007), where 1 g CH_4 and 1 g N_2O are equivalent to the global warming potential of 25 g and 298 g CO_2 at 100 year time horizon, respectively.

Carbon (C) sequestration (kg C ha^{-1} yr^{-1}) was calculated as follows:

C sequestration = net primary production + C in manure – soil organic C decomposition – C in harvested products --- Equation (1)

Soil organic C decomposition (kg C ha^{-1} yr^{-1}) = 49.7× (Water filled pore space (%))＋ 217.0× (soil temperature at 5cm (° C)) - 144.8× (CN ratio) - 58.7× (clay content (%)) + 2807.3 (P＝0.012) --- Equation (2)

For Soil organic C decomposition for perennial vegetation such as grassland and abandoned area a fixed value of 1691.3 kg C ha^{-1} yr^{-1} (Mu et al. 2008a) was used.

Nitrous oxide flux (kg N ha^{-1} yr^{-1}) of an upland field was estimated using emission factors (EF: proportion of N_2O emission to applied nitrogen) on the basis of the following assumption (Toma et al. 2007):

N_2O flux = EF chemical fertilizer × applied chemical fertilizer
+ EF organic matter × applied organic matter + background N_2O emission
--- Equation (3)

The EF was created for onion fields. To consider the difference in CN ratio of different crop residue, the EF was parameterized following Toma and Hatano (2007). Since the background N_2O emission was only measured at cultivated fields and the rate was higher than the reported values for background emission, a fixed value of 1 kg N ha^{-1} yr^{-1} (Intergovernmental Panel on Climate Change 1996) was used for fallow and bushes.

The CH_4, CO_2 and N_2O flux for a paddy rice field showed a high correlation with the applied amount of straw and were expressed as a function of amount of straw residues (Naser et al. 2007).

Farmland surplus N (kg N ha^{-1} yr^{-1}) was calculated based on equation 4 and 5. Note that the plant residue is considered as input and the total N uptake by plants as output. Thus the actual output is only the harvested N in plant.

Farmland input N = chemical fertilizer + manure + green manure + residue
+ biological N_2 fixation + deposition and irrigation --- Equation (4)

Farmland surplus N = N input to farmland – total N uptake by plants (yield plus residue) – denitrification

– NH_3 volatilization from chemical fertilizer and manure – N_2O emission

--- Equation (5)

A ground survey was conducted in 2002, 2005 and 2007 to locate the land uses and the land use distribution was mapped digitally using ArcView 9. Land use history was analyzed using 1:25,000 maps from geographical survey institute (1959, 1966, 1976, 1988, 1994). Fallow was defined as area with previous artificial land use but no cultivation or construction in the ground survey years. The area which was identified as fallow since 1994 was termed ‘abandoned area’. Farmer’s interviews were conducted in 2002, 2005 and 2007 to obtain information on management practices and land use distribution in the study area. Questionnaires were distributed to farmers where information on amount and type of fertilizer, timing of application, incorporation methods and final yield were obtained. There were 161 farms in 2002 in this area. Among them 34 were sown to paddy rice, 14 to wheat, 3 to soybean, 49 to onion, 19 to vegetable, 3 were grassland, and 5 were fallow. Yield values were multiplied by the ratio of main product to by product (Matsumoto 2000) to calculate the net primary production and amount of N in the crop by measuring the CN ratio (SUMIGRAPH NC－1000, SHIMADZU, Kyoto, Japan). Values not obtained from our monitoring were obtained from literature (see Kimura et al. 2007 for more detail). Productivity was evaluated by multiplying the price of sold product by area for each year (Ministry of Agriculture, Forestry and Fishery 2009a).

Result and discussion

Land-use change from 2002 to 2007

Urban area was the largest artificial land use with occupying about 28% of the landscape throughout the 3 investigated years (Figure 2). The next largest land use was fallow, due to the closure of mine activity in 1989 (Mikasa City 1994) and recent agricultural activity in this area (Kimura et al. 2004). Among farmlands, paddy rice occupied the largest land area (14%) followed by onion (11%) in 2002. Both paddy rice and onion declined to 2% from 2002 to 2007. The decline in paddy rice area is encouraged by the set aside policy of the Japanese government (Ministry of Agriculture, Forestry and Fishery 2007). The decline in onion area might be due to the low onion price in 2002 as described later. Grass and vegetable increased in extent during this period. Cultivation of fodder crop, soybean and fodder crops were substituted by the Japanese government (Ministry of Agriculture, Forestry and Fishery 2009b). The increase in grass from 6% to 10% might have been driven by the by this set aside policy.

Farmland management

Nitrogen input for the main land uses was calculated as the sum of chemical fertilizer, manure, green manure and crop residues, biological N_2 fixation and N from deposition and irrigation (Table 1). The highest input for paddy rice, wheat, onion and vegetable derived from chemical fertilizer, whereas that for soybean and grass was from biological N_2 fixation and manure, respectively. The highest N input for fallow and abandoned area was from green manure. Total input was highest for onion at 487.7 kg N ha^{-1} yr^{-1}, followed by vegetable at 423.1 kg N ha^{-1} yr^{-1}. The standard deviations were very high for both land uses, indicating very low N inputs for some fields. Exceptionally high deviations were also observed for manure applications. Grass showed the third highest N input with 204.9 kg N ha^{-1} yr^{-1}. The lowest N inputs were found for fallow and abandoned area with 94.2 and 85.0 kg N ha^{-1} yr^{-1}, respectively. Some fallow areas were fertilized and cultivated with green manure, thus, there was a high deviation in chemical fertilizer input.

The Nitrogen in yield did not differ greatly among the years, except for paddy rice and vegetable (Table 2). Paddy rice had the lowest amount of 49.0±4.3 kg N ha^{-1} yr^{-1} in 2002. Farmers with yields much lower than the average might have been included in the investigation 2002. The higher yield of vegetable in 2005 and 2007 compared to 2002 is due to including more vegetable types in 2005 and 2007 than in 2002. The inclusion of various vegetable types also increased the standard deviation. The FSN was calculated using the equation 4. Farmland surplus N showed consistent tendency throughout the years. Onion had the highest surplus ranging from 154.5-187.5 kg N ha^{-1} yr^{-1}, followed by the vegetables (128.6-172.3 kg N ha^{-1} yr^{-1}). Fallow and abandoned area showed a FSN of 15.5-20.3 and 6.8-12.3 kg N ha^{-1} yr^{-1}, respectively. Paddy rice showed as low FSN as fallows, whereas the lowest FSN was found for soybean with negative to slightly positive amount.

Income for main land uses in 2002, 2005 and 2007 are shown in Table 3. The difference in the values is mainly due to fluctuations in market prices. There were high variations for paddy rice, soybean and vegetable. The highest income per ha was for vegetable in 2002, soybean in 2005 and rice in 2007. In 2005 and 2007, the lowest income was found for grass followed by onion. The income for grass might be lower in reality, since this cost was calculated for commercial hey and the grass is not sold but consumed inside the farm in this region.

Global warming potential of the soils

The average GWP for the major land uses are shown in Figure 3. Calculations of GWP were based on soils occupied by the different land uses (Hokkaido Central Agricultural Experiment Station 1971). Paddy rice and soybean showed the highest GWP of more than 10 Mg CO_2 eq ha^{-1} yr^{-1} throughout the investigated period. Methane accounted for 75% of the GWP for paddy, whereas both N_2O and CO_2 were responsible for the relatively high GWP for soybean. The lowest GWP was observed for abandoned land as the relatively high amount of plant biomass lead to lower N_2O emission and higher carbon sequestration compared to other land uses. Changes in GWP for other land uses were observed between 2002 and 2007 due to differences in N_2O emission and soil carbon decomposition. Low emissions of N_2O or organic fertilizer application in 2007, possibly led to negative GWP for abandoned area, fallow and wheat.

Global warming potential is higher for paddy rice fields and soybean than a previous study (Kimura et al. 2007) apparently due to the increase from 22-57 farms to 127 farms in the current study. In the new inventory, more farmers were included who incorporate green manure and livestock manure into the production system. The standard deviation is higher, but the value might reflect more precisely the real situation in the study area. The calculation of N_2O emission as well as soil carbon decomposition has also been improved compared to the previous study to reflect climate and soil properties. N_2O emission as high as 15.6 kg N ha^{-1} yr^{-1} had been recorded in this region in recent years (Kusa et al. 2002). High background emission ranging from 1.81-12.1 kg N ha^{-1} yr^{-1} may also be playing a role (Toma et al. 2007). The GWP reported for upland crop for European Union countries was 0.7–25 Mg CO_2 eq $ha^{–1}$ $yr^{–1}$ with an average value of 2.0 Mg CO_2 eq $ha^{–1}$ $yr^{–1}$ (Freibauer 2003). The value in the present study might not be extremely high compared to this result. The comparison of the 3 years shows that global warming potential may change dramatically if the amount of residue and/or soil respiration changes, as shown in the case of wheat.

The cumulative GWP for the whole farmland area declined from 14,184 Mg CO_2 yr^{-1} in 2002 to 8337 Mg CO_2 yr^{-1} in 2007 (Figure 5). The contribution of paddy rice was highest ranging from 54% in 2005. to 90% in 2007 The high amount (11085 Mg CO_2 yr^{-1}) in 2005 was also due to high GWP of wheat and onion, with each contributing 12% of the total amount. In 2005, the reduction in GWP was mainly due to upland crops except fallow. Fallow in 2005 showed a high GWP of 4.9 Mg CO_2 ha^{-1} yr^{-1} and accounted for 28% of the total emission. This might be due to increasing N_2O emission from green manure. On the other hand, fallow showed a negative GWP per area in 2007 and reduced the total GWP. Due to lower GWP also for other land uses, the overall GWP in 2007 was lowest among the years.

Eco-balance Analysis

The eco-balance analysis was used to compare different environmental loads with farm productivity (Kimura and Hatano 2007). The GWP and FSN were each compared with farm income for the 3 investigated years (Figure 5). Global warming potential, FSN and income outcomes under the prevailing agronomic management methods are obtained only in the zone surrounded by the solid line in Figure 5. This 'feasible zone' changed among the years based on farmers' land use strategies and other agronomic conditions. For instance, the feasible zone for GWP and income is narrower for 2005 and 2007 compared to 2002. The shapes indicate that for 2005 and 2007 higher income is only possible through an accompanied increase in GWP. This relationship is particularly true for rice and soybean. FSN on the other hand showed different relation to income compared to GWP. High income did not coincide with high FSN in 2005 and 2007, indicating that aiming at higher income would not necessary result in higher FSN environmental load. Soybean and rice manifested low FSN–high income relationship (Figure 5). The area with the slashed lines in Figure 5 indicates reductions in GWP and FSN that will still maintain the present income level by changing the land use combinations in the given agronomic management methods.

To ascertain the land use combinations meeting these requirements, possible land use combinations were calculated using an Excel Spreadsheet by changing the land use proportions from 0 to 100% at 10% increments.1 The total number of land uses computed was 8,008 and was validated using a combinatorial composition formula (Skiena 1990). Out of this, the number of land uses that reduced both GWP and FSN and achieved the same or higher income level was 936 for the year 2002, 901 for the year 2005 and 692 for the year 2007 (Table 4). The average income increased 1.17-1.26 compared to the average of each year, while GWP and FSN reduced by 0.67-0.79 and 0.72-0.77, respectively. The number of land use combinations meeting all requirements in the three investigated year were 290 (Figure 6). For almost all combinations, high proportion of wheat and abandoned area was found. Even though, wheat did not have the smallest amount of FSN and showed the third highest GWP in 2002, the quite stable price and that it showed no extremely high value acted as an advantage. The land use with high income (rice, soybean and vegetable) showed either high GWP or FSN so that their incorporation was only possible by including the abandoned area, which had mitigating effect of GWP and low FSN. Abandoned area was included in 259 combinations ranging from 10-40%, indicating that some mitigation measure is necessary to increase income without increasing environmental load.

This eco-balance analysis is a holistic approach to visualize the relation of environmental load and income. The present analysis showed that there is not necessarily a trade-off between environmental load and income. Our analysis showed that even in such case income can still be increased while reducing the GWP through different land use strategies. A similar holistic approach to evaluate land uses is the ecological footprint method (Liu et al. 2008). The ecological footprint calculates how much land area is required to compensate the environmental load caused by human activity. But this approach does not have a boundary and is rather an abstract concept. The eco-balance analysis shows concrete measure to balance environmental load and benefits from farming for a given region.

The eco-balance analysis also shows the specific characteristics of land uses in the investigated region. Weak points of land uses can be found and changes in management methods can be suggested. For example, paddy rice and soybean cultivation will be highly recommended due to their high income and low FSN, if the GWP could be reduced. Reduction of residue input or changing the timing of its incorporation (Yagi et al. 1997) would be necessary for paddy rice, while addition of green manure might be recommended in case of soybean. On the other hand, substitution by the government as for set aside policy

(Ministry of Agriculture, Forestry and Fishery 2009b) might be provided to enhance those land uses with low income and low GWP and FSN like abandoned area. The fallow and abandoned areas do not have any economic value in this analysis. However, increasing soil quality due to green manure cultivation can increase the yield in the succeeding crop (Mallory and Porter 2007). Carbon mitigation might become also of economically valuable if carbon credits are applied to soil carbon sequestration.

The GWP, FSN and yield values in the analysis are calculated from mean values of the whole region. Different soil type has different influence on greenhouse gas emission as well as nitrate leaching or NH_3 emission (Sutton et al. 2000, Franzluebbers et al. 2001, Tan et al. 2009). A GIS based analysis considering the soil type in the land use combination analysis may improve the accuracy of the analysis. Further analysis should also take into account the costs for material, machinery use and labor which were not subtracted from the income at present. Carbon credit may also change the relative position of each land use in Figure 4. It should be kept in mind that relationships between environmental load and income are not fixed – they change dynamically due to environmental condition and economic situation. The present analysis is a tool to analyze the present situation and suggest optimization measures.

Conclusion

This study showed how monitoring data can be used in eco-balance analysis to screen land use combinations that address environmental as well as economic concerns. The target value of environmental load or crop production can be changed according to the environmental and economic condition of the investigated area. This is a relative analysis for each area and monitoring data or some measure to estimate the nutrient flow must be obtained. Using this analysis, incentives to choose land use combinations with lower environmental load can be created.

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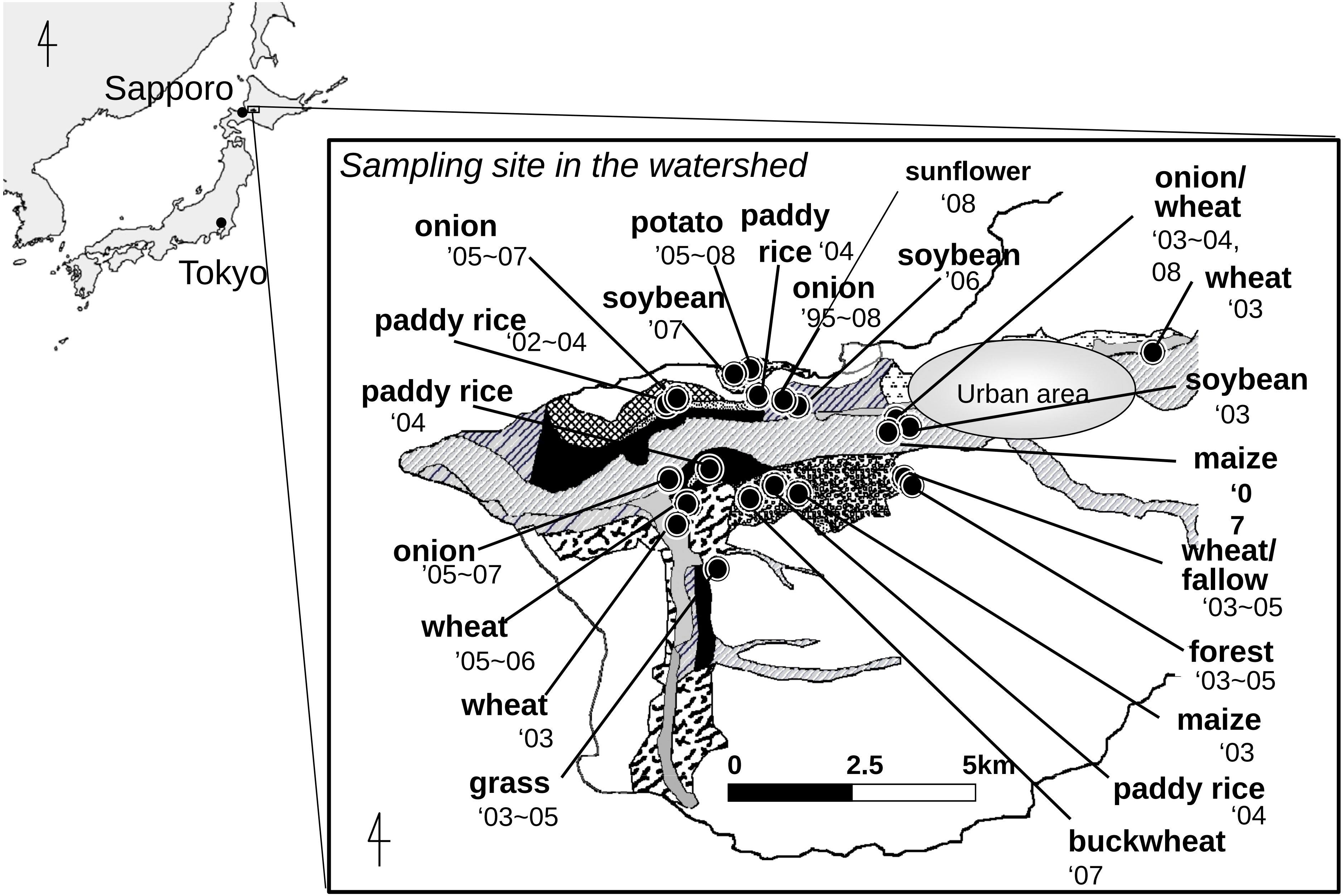

Fig. 1 Sampling sites in the Ikushunbetsu River basin of different land uses for different years. Map shows the boundary of the basin illustrated in different soil series.

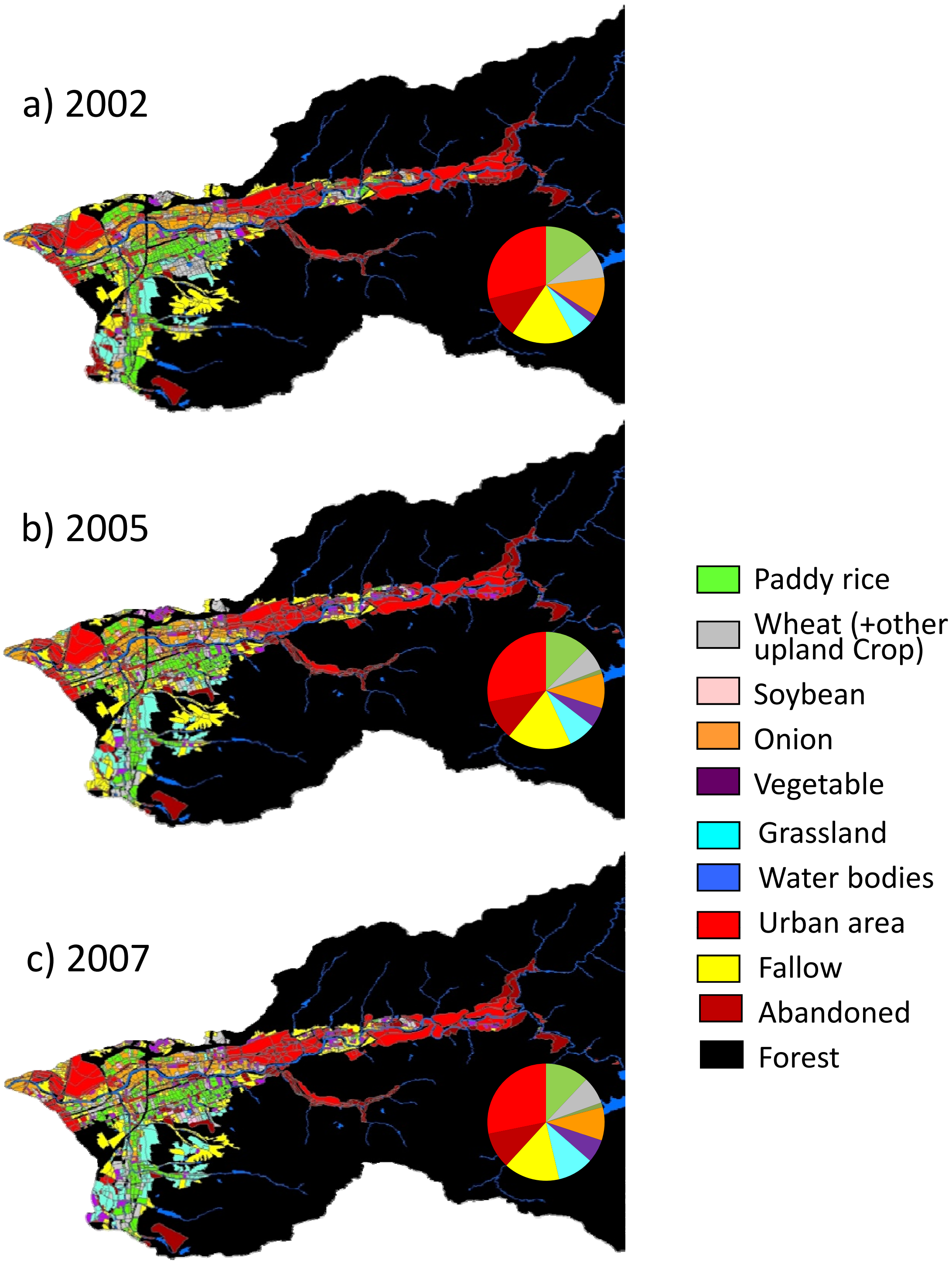

Fig. 2 Distribution of land uses in Ikushunbetsu watershed in 2002, 2005 and 2007. The Pie graph shows the proportion of each land uses.

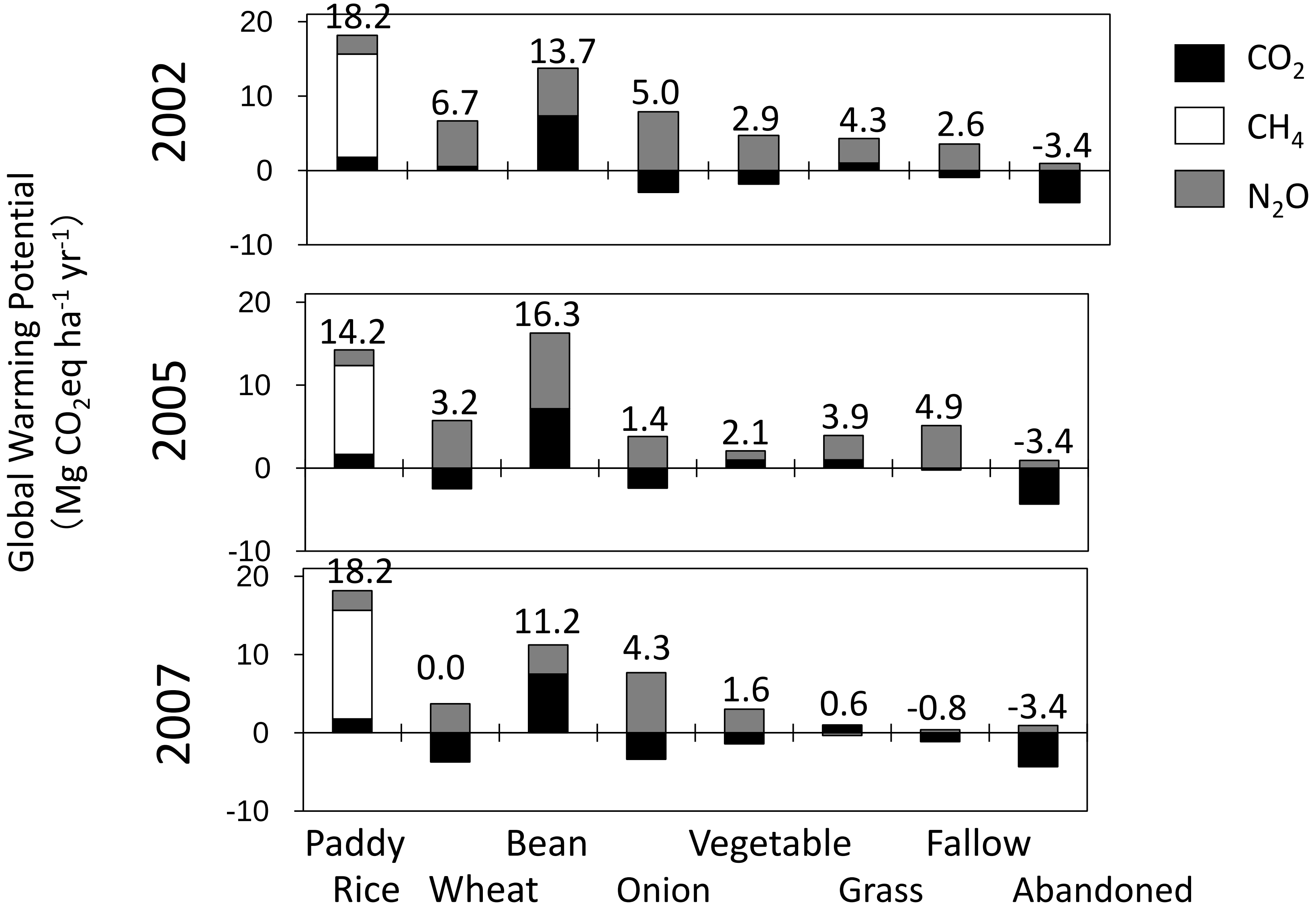

Fig. 3 Weighted mean of global warming potential of main artificial land uses in Ikushunbetsu watershed in 2002, 2005 and 2007.

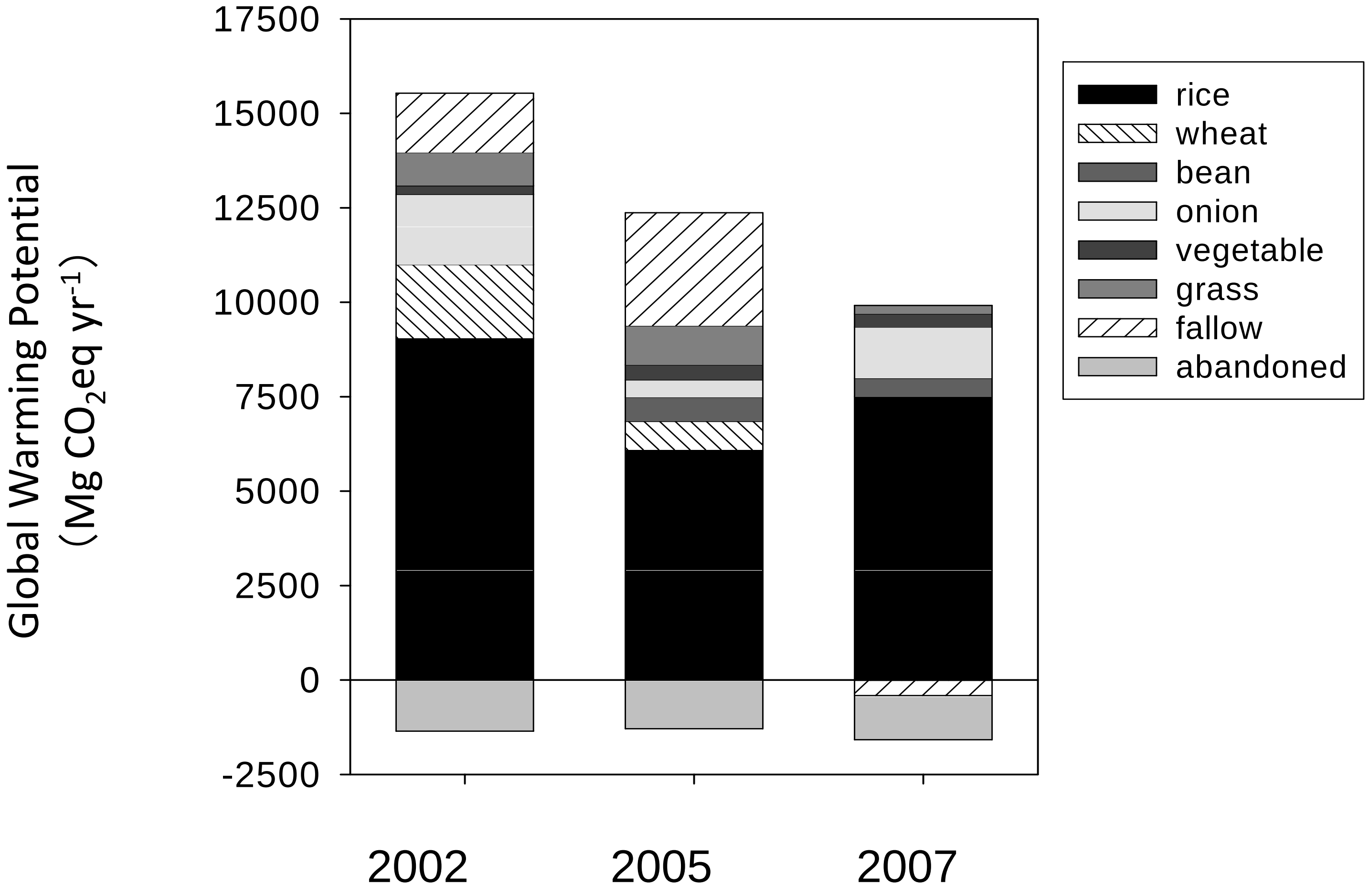

Fig. 4 Total amount of global warming potential in the region and the contribution of the main land uses in Ikushunbetsu watershed in 2002, 2005 and 2007.

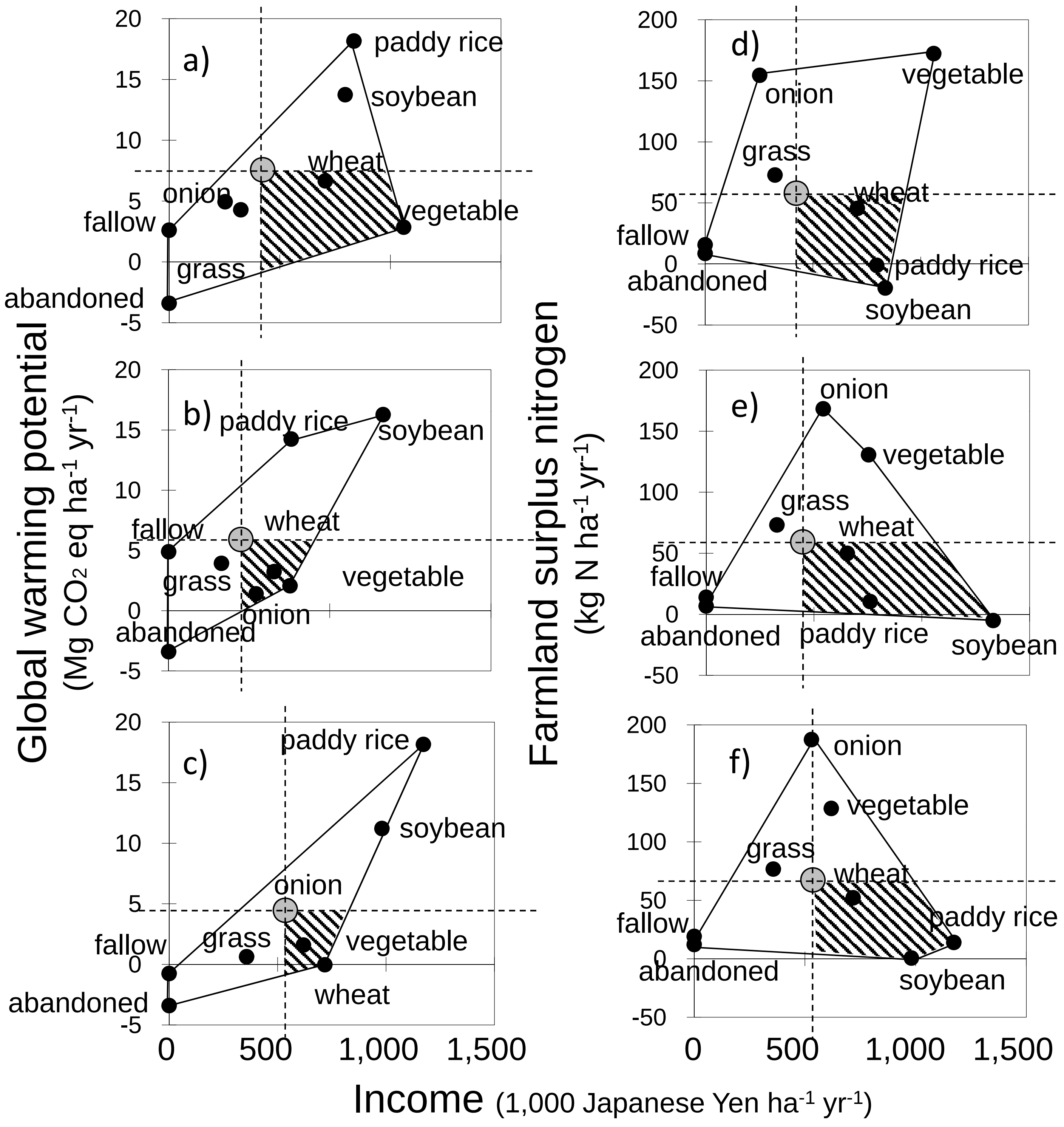

Fig. 5 Relation of global warming potential (GWP) to income for a) 2002, b) 2005 and c) 2007, and relation of farmland surplus nitrogen (FSN) to income for d) 2002, e) 2005 and f) 2007. The gray big circle represents the watershed average in each year, the black small circles represents the value if only one land use occupies 100% of the watershed. The dotted lines indicate the value of income, GWP and FSN in each year, the area with the slashed lines indicate the values of GWP and FSN which can be reduced from the present situation while maintaining the income by changing the land use combination.

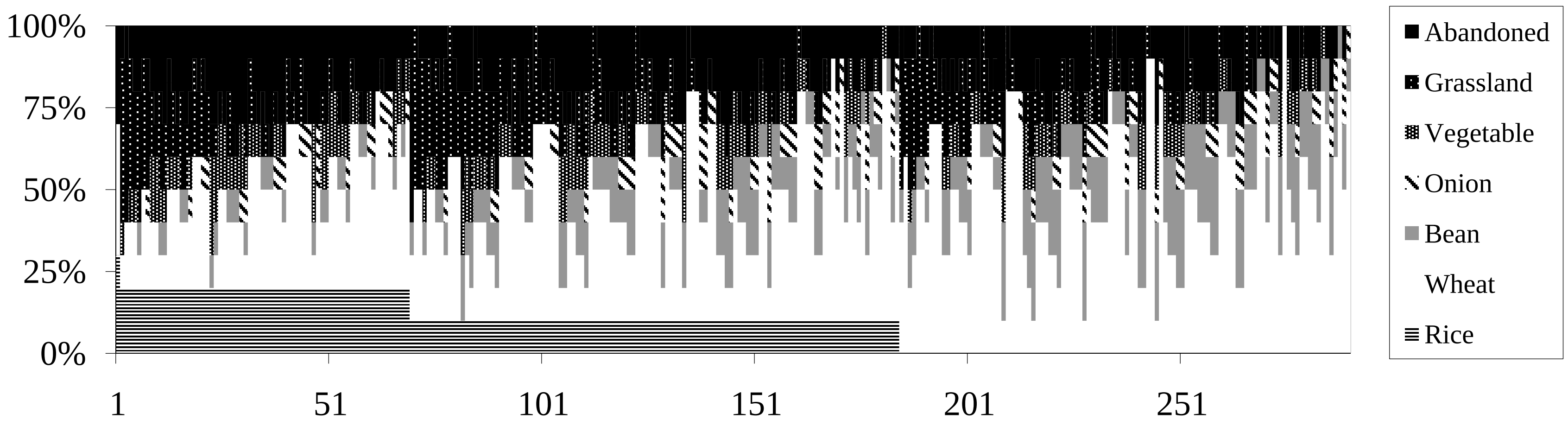

Fig. 6 Land use combinations meeting increasing the income, while reducing the GWP and FSN in all three years.

Table 1 Average Nitrogen input for the main land uses from 2002 to 2007

	paddy rice		**wheat**		**soybean**		**onion**		**vegetable**		**grass**		**fallow**		**abandoned**	
	ave	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**
Chemical Fertilizer	79.8	(23.5)	106.4	(61.7)	25.3	(6.2)	282.4	(121.9)	195.5	(224.7)	40.7	(9.0)	9.2	(26.6)	0.0	0.0
Manure	4.9	(18.0)	25.0	(46.3)	0.0	0.0	77.9	(181.4)	122.1	(159.5)	120.3	(26.3)	0.0	0.0	0.0	0.0
Green Manure + residue	14.3	(12.8)	19.5	(4.5)	28.2	(0.7)	114.5	(73.6)	91.1	(27.6)	16.4	(8.2)	72.1	(37.8)	72.1	(37.8)
N_2 fixation	30.0	(15.0)	5.0	(2.5)	93.0	(46.5)	5.0	(2.5)	5.0	(2.5)	19.6	(9.8)	5.0	(2.5)	5.0	(2.5)
Deposition + Irrigation	15.4	(7.7)	7.9	(3.9)	7.9	(3.9)	7.9	(3.9)	9.4	(4.7)	7.9	(3.9)	7.9	(3.9)	7.9	(3.9)
sum	144.3		163.7		154.4		487.7		423.1		204.9		94.2		85.0	

Table 2 Nitrogen in yield and farmland surplus N (FSN) in 2002, 2005 and 2007.

		paddy rice		**wheat**		**soybean**		**onion**		**vegetable**		**grass**		**fallow**		**abandoned**	
		ave	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**	**ave**	**(sd)**
2002	Yield	49.0	(4.3)	65.6	(15.1)	104.6	(2.5)	138.7	(23.5)	93.9	(28.5)	81.8	(20.8)	0.0		0.0	
	FSN	19.5		45.5		-1.1		154.5		172.3		72.9		15.7		8.6	
2005	Yield	60.8	(6.7)	62.5	(31.9)	104.6	(2.5)	132.1	(18.5)	143.9	(116.8)	81.8	(20.8)	0.0		0.0	
	FSN	10.5		50.0		-5.1		168.3		130.7		73.2		15.5		6.8	
2007	Yield	58.2	(7.5)	62.5	(31.9)	104.6	(2.5)	108.8	(28.9)	143.9	(116.8)	81.8	(20.8)	0.0		0.0	
	FSN	14.0		52.2		0.7		187.5		128.6		76.8		20.3		12.3	

Table 3 Income for the main land use in 2002, 2005 and 2007 (1,000 JPY ha^{-1} yr^{-1}).

	paddy rice	**wheat**	**soybean**	**onion**	**vegetable**	**grass**
2002	835.4	705.8	795.8	253.1	1,060.2	324.0
2005	760.6	654.7	1,331.2	542.9	753.2	328.1
2007	1,172.2	717.8	980.9	529.4	619.0	357.2

Table 4 Watershed average income global warming potential (GWP), farmland surplus N (FSN) for each year at present and for the Eco Balance scenarios . No indicate the number of land use combination meeting the Eco-balance scenario criteria.

	Watershed Average			**Scenario Result**				**Scenario／Year average**		
	Income (,1000 Yen ha^{-1})	**GWP** (Mg CO_2 eq ha^{-1})	**Surplus N** (kg N ha^{-1})	**No**	**Income** (,1000 Yen ha^{-1})	**GWP** (Mg CO_2 eq ha^{-1})	**Surplus N** (kg N ha^{-1})	**Income**	**GWP**	**Surplus N**
2002年	422.7	7.6	58.0	936	524.1	6.0	41.7	1.24	0.79	0.72
2005年	448.1	5.9	59.3	901	562.4	4.4	44.1	1.26	0.75	0.74
2007年	535.9	4.5	67.4	692	627.4	3.0	52.2	1.17	0.67	0.77