CO₂-GREENHOUSE GAS-REDUCING POTENTIALS OF SOME ECOLOGICAL AGRICULTURE PRACTICES IN THE PHILIPPINE LANDSCAPE

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Of the 26 Bt of CO₂ loaded into the atmosphere yearly, 4 Bt is the contribution of agriculture and land clearing alone. Agriculture contributes to carbon dioxide-greenhouse gas (CO₂-GHG) emission into the atmosphere in at least three ways. One, as soils are eroded, the sequestered soil organic C are released as CO₂ to the atmosphere; two, monocropping results in bare soil and CO₂ sequestration via plant photosynthesis in a monoculture is considerably lower than that in a forest ecosystem; and three, adoption of fossil fuel-based inputs agriculture coupled with intensive postharvest handling and distribution sums up to a significant amount of CO₂ emission into the atmosphere.

Some ecological agriculture practices are characterized as to their CO₂-GHG soil-sequestering and emission-reducing potentials. Also, the potentials of each of these ecological agriculture practices if adopted or practiced in the Philippine landscape are evaluated. On a yearly basis, the estimates show that green manuring can reduce up to 9.12 Mt CO₂, for in-situ composting or crop biomass recycling (no burning of residues) at 11.66 Mt CO₂, and 12.85 Mt CO₂ for tree-integration in the agricultural landscape or a total of 33.61 Mt CO₂.

The CO₂-GHG contribution of agriculture can be significantly reduced. This could be done by adopting ecological agriculture practices such as green manuring, mulching, composting, and tree integration in the agricultural landscape. Also, reduced tillage and no burning of crop residues are practices that can also contribute in the reduction of CO₂-GHG emission into the atmosphere.

To reduce significantly the associated CO₂-GHG emissions from food systems, it is necessary to pursue localized, small-scale and family-based food production schemes. Large-scale and highly mechanized agriculture requires tremendous amounts of energy in transporting, processing, storing and distributing the products. On the consumption side, eating food lower in the food chain (less animal protein) and consuming freshly gathered rather than refrigerated and processed foods can significantly reduce GHG load in the atmosphere. A food systems audit to precisely estimate the CO₂-GHG emissions from field level production and up to the time food is consumed is recommended.

Keywords atmosphere, biomass recycling, carbon dioxide, CO₂-sequestration turnover, composting, ecological agriculture, energy, family-based food production, food systems, forest ecosystems, fossil fuels, greenhouse gas, green manuring, mechanized agriculture, mulching, photosynthesis, postharvest handling

INTRODUCTION

Agriculture contributes significant amounts of carbon dioxide-greenhouse gas (CO₂-GHG) emissions to the atmosphere. Of the 26 Bt CO₂ loaded to the atmosphere yearly, 4 Bt is contributed by agriculture and land clearing for urban development (Sierra Club 1998). While half of this CO₂ is being absorbed by plant life and the oceans, the rest steadily accumulates in the atmosphere. Carbon dioxide concentrations in the atmosphere are currently 30% above the levels that prevailed prior to the industrial revolution (IPCC 1995).
Greenhouse gases other than CO₂ include methane, most of which come from natural gas, livestock manure and urine, landfills, and Asia's rice lands; and nitrous oxide, which is released from cars, fertilizers and nylon production. Coolants in air conditioners and refrigerators are also very powerful greenhouse gas contributors. Greenhouse gases trap heat, which in turn raises temperatures and changes climate systems like atmospheric and ocean orientation, and precipitation patterns. Scientists are predicting temperature increases between 1 and 3.5°C by the year 2100 (IPCC 1995).

CO₂ emission from burning fossil fuels accounts for 75% of the enhanced greenhouse effect (Rolfe 1998). The other 25% is contributed by deforestation (10%) and agriculture (15%). This data shows that reducing CO₂-GHG emissions will be more significant if the CO₂ emission from burning fossil fuel is the focus. While this extrapolation may be valid, it is sending a different signal to agriculture. It is making the farmers, the policy makers and society at large complacent on the thought that there is no sufficient cause for alarm to the present largely fossil-fuel oil based inputs dependent agricultural systems and practices as they contribute only minimal amount to the yearly CO₂-GHG emissions.

It is important to point out that the reported CO₂-GHG contribution of agriculture includes only the primary aspect of production. If computed on the basis of food systems (as shown in Figure 1) the CO₂-GHG emissions above would increase considerably. Producing, storing, processing or transforming primary agricultural products to various consumable forms and distributing these products consumes a lot of fossil-fuel-based energy. In US, it takes 13-14 calories of energy to produce, transport, process, store, distribute 1 cal of food. The US loses its CO₂-sequestering property, as plant photosynthesis is much diminished.

In this paper, the CO₂-GHG-reducing agricultural practices are characterized as to how each practice contributes in reducing CO₂-GHG emissions or in sequestering back CO₂ into the agricultural landscape. Also, the CO₂-reducing or sequestering effects of each practice are quantified. Options on how the agricultural landscape can perform both the food production and CO₂-sequestering functions are discussed.

**CO₂-GHG-DECREASING & SEQUESTERING PRACTICES**

Agricultural practices can reduce CO₂-GHG
emissions in at least two important ways, and they are as follows: 1) They decrease CO$_2$-GHG load in the atmosphere. Zero emission may not be achievable even in organic farming since land preparation and crop establishment, hauling, transport, processing, storage will still use fossil-fuel energy, thus emitting CO and CO$_2$; and 2) They sequester back CO$_2$ both aboveground (plant biomass) and below ground (soil biomass). Summarized in Box 1 are the low CO$_2$-GHG-loading and CO$_2$-sequestering agricultural practices. It is worthy to mention that these practices are not new especially among the practitioners of organic agriculture (OA). They are being revisited to highlight their significance in connection with the present goal of reducing the CO$_2$-GHG load in the atmosphere.

**Reduced/minimum tillage.** While tillage is understandably done to facilitate crop establishment as in the preparation of suitable seedbed, leveling, burying crop/weed residues, it unintentionally leads to an increased soil-C loss. How tillage increases soil C-loss, thereby contributing to CO$_2$-load in the atmosphere is shown in Figure 2. Thus, tillage enhances aeration, which stimulates microbial activity and enhances soil decomposition, in turn disrupting soil aggregation, which increases risk of soil erosion - all these increasing soil C-loss.

Therefore, adoption of practices that reduce tillage is beneficial as they 1) decrease the energy (farm power) used in fossil-fuel burning, thereby reducing CO$_2$ emission into the atmosphere (Soriano 1982, Mendoza 1989) and 2) contribute to significant accumulation of soil-C (Lal et al 1998, Paustian et al 1995) due to reduced soil erosion, and slower soil organic matter decomposition. Reducing or minimizing tillage, however, should not be replaced with or result in an intensified use of herbicides, as this will increase the energy bill due to herbicide manufacture.

**Green manuring.** The physical process of N fertilizer manufacture is very fossil fuel-energy intensive at 17.6 Mcal/kg or 3.59 LDOE (Soriano 1982). In contrast, with green manuring, the biological N fixation through the legume-Rhizobium symbiosis has the following effects: 1) sequesters back CO$_2$ through plant photosynthesis, 2) eliminates the need to burn fossil fuel energy if only to manufacture N, thereby reducing the CO$_2$-GHG load in the atmosphere at 10.7 kg CO$_2$/kg N (Nebel & Wright 1996), and 3) plowing under the green manure crop is sequestering back CO$_2$ in the form of humus-C. The other direct/indirect benefits of green manuring in CO$_2$ sequestration and/or decreasing CO$_2$-GHG load in the atmosphere are listed in Box 2. Thus, green manuring is “hitting two birds with one stone,” ie, it provides both ecological benefits as has just been pointed out, and economic benefits as it reduces the cost of production (no buying of inorganic fertilizer). Present organic farming practitioners see green manuring as an indispensable practice. However, to make an ecological impact, it must be practiced by many if not all farmers.

**Composting.** Technically, composting is the induced decomposition and transformation of organic materials like plant refuse and residues of food, with the intention of producing humus (Scheeve 1998). It is a practice that recycles organic matter back into the soil. Thus, it is facilitating soil CO$_2$-sequestration. The agroecological roles of humus (Hodge 1998, Scheeve 1998) are well known (Box 3); here, they are being revisited to emphasize the unique contribution of composting in decreasing CO$_2$-GHG load in the atmosphere as follows: 1) reduction or substitution of chemical fertilizer, which
has the effect of reducing fossil-fuel oil burning for the manufacture of fertilizer, 2) reduction of tillage intensity, which improves soil tilth (reduced fossil-fuel oil use lies in reduced land preparation), 3) reduction of irrigation frequency due to improved soil water retention capacity (reduction in pumping water for irrigation), 4) enhancing crop photosynthesis/crop growth, as humus serves as stock of nutrients for higher plants, which increases the sequestration of CO$_2$ in the atmosphere through crop photosynthesis, and 5) humus being the source of several active agents, plant hormones, antibiotics, and B vitamins such as pantothenic acid and riboflavin (Rateaver & Rateaver 1973). This explains why crops are healthier and more productive, and why they are better able to resist pest infestation. This eliminates the need to apply pesticides, which eliminates pesticide production that utilizes huge amounts of fossil fuel. Pesticide manufacture utilizes an equivalent of about 5.54 L of gasoline with an equivalent amount of CO$_2$ in the atmosphere when they burn, these residues are recycled back to the soil as humus (Mendoza & Samson 1999). The burning of crop/weed residues has been a rampant and widespread practice in the Philippines, particularly, in rice and sugarcane cultivation. Estimates of CO$_2$-GHG load in the Philippines reveal considerable amounts (Mendoza & Samson 1999). Figure 5 shows the interactive (additive) effects of crop residue burning in relation to greenhouse gasses (GHG) load in the atmosphere. It is burning crop residues, practiced by many farmers, that have far-reaching contributions to CO$_2$-GHG emissions. In particular, rice and sugarcane residues burning contribute about 4.46 Mt of C/year, or 16.33 Mt of CO$_2$ in the atmosphere if all the C-liberated through burning is converted into CO$_2$. It has been estimated that for the last 80 years, about 177.5 Mt of C through crop residue burning was loaded into the atmosphere. This is still small compared with the 2.7 Bt (Lasco 1998) of C-lost due to deforestation (from 15.7 Mha) of Philippine tropical forest. The CO$_2$-GHG contribution of rice and sugarcane production for the last century is about 6.6% of the total GHG contributed by deforestation starting 1900. While this is small, it is still a major loss of energy from the ecosystem, as it amounts to 4.46 Mt.

**Box 2** Direct & indirect roles of green manuring in agriculture as well as in CO$_2$ sequestration & decreasing CO$_2$-GHG emissions into the atmosphere

- Eliminates the need to burn fossil fuel energy (needed for manufacture of fertilizers), thereby reducing CO$_2$-GHG load in the atmosphere
- Plowing under the green manure crop sequesters back CO$_2$ in the form of humus-
- Benefits to the soil
  - Adds/replenish soil organic matter
  - Improves activities of soil microbes
  - Improves soil physical condition overall
- Increases P availability
- Minimizes compaction
- Improves activities of soil microbes
- Increases water retention
- Improves soil particle aggregation
- Improves aeration, water infiltration

Contributes immensely to decreasing the CO$_2$-GHG load in the atmosphere through the following: 1) reduces eliminates the need for applying herbicides as the mulch suppresses weed growth, thereby reducing fossil-fuel oil burning needed in herbicide manufacture, 2) eliminates reduces the need for tillage, reducing fossil-fuel oil burning by the machines used in tillage including the manufacture of machines, 3) conserves improves water retention and makes crops more drought tolerant, reducing fossil-fuel oil burning for pumping water, 4) maintains soil sequestered C as it protects the soil from erosion, and finally, 5) mulching means no burning of crop or weed residues. Instead of loading CO$_2$ and N$_2$O- GHG in the atmosphere when they burn, these residues are recycled back to the soil as humus. Humus becomes stable soil C until further degraded or eroded.

**Box 3** Agroecological roles of humus (summarized by Scheeve 1998)

- Humus serves as stock of nutrients for higher plants.
- Humus is the source of several active agents, plant hormones, antibiotics.
- Humus increases soil biological activity, thus, limiting adverse organismal activities:
  - Humus supports N-fixing organisms that supply additional N to crops.
- Humus enhances the physical and chemical properties of soil:
  - Enhances soil cation exchange capacity
  - Improves the soil waterholding capacity (+ to 5 x more than clay, humus absorbs water 80-90% of its weight)
  - Acts like glue, linking mineral soil particles to so called clay-humus complexes, thus improving soil particle aggregation
- Humus reacts with many substances to form complexes:
  - Reacts with oxides of iron and aluminum to form stable aggregates, thus reducing toxic metal concentrations (Wild 1993)
  - Reacts with herbicides applied in the soil (Vaidyathan & Eagle 1993)
  - Humus serves as buffer system for the pH value in the soil

Cited in Mendoza and De Los Santos (1959)

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annual C-loss. Assuming an energy value of 17 GJ/t of these residues, a total of 75.6 M GJ of energy is being lost. The annual energy equivalent of burning crop residue (rice and sugarcane only) is about 13 M barrels of oil.

It is recognized that the released CO₂ is mostly absorbed during plant growth, thus, the net CO₂ load into the atmosphere is not that high. The CO₂-GHG reduction from not burning crop residue results primarily from the interactive/additive effects of improving soil organic matter. Non-crop residue recycling has been attributed to soil fertility decline (Aggarwal 1994, Velayuthem & Bhandivaj 1994, FAO 1982). Chemical fertilizer application has considerably increased over the years in rice and sugarcane production, i.e., 0.2-0.4 bag/ha/year for rice and 0.3-0.5 bags/ha/year for sugarcane (Mendoza 1989). The heavy usage of chemical fertilizers in these 2 crops contributes massive CO₂-GHG emissions.

Tree-integration in the agricultural landscape. The annual crop-dominated agricultural practice in the past century was largely specialized, monocropped and machine-tailored especially in the highly industrialized economies. Intensive monoculture for our major food crops (rice, corn, wheat, sugarcane and major vegetables) in the tropics is a common practice. As an agricultural practice, monocropping of annual food crops largely excludes trees in the landscape. Asia, which accommodates two-thirds of the world population, has the highest land clearing (deforestation) rate, which in turn leads to higher agricultural-to-forest-land ratio. The Philippines in particular, is no exception considering the

![Diagram of mulching benefits](image)

Figure 4. The interrelationships of mulching and how these benefits lead to reduction of CO₂ loading in the atmosphere.
severely deforested status of our forest areas (Lasco 1998, Lasco & Pulhin 1998). The need to provide adequate food, feed, fiber, and fuel to the growing population is the rationale for the land-use change from forestlands to croplands, or from diverse to specialized ecosystems.

Tree-integration in the agricultural landscape could be done through the following scheme: a) perimeter or boundary planting of farmlots; b) sparse-planting (10 m x 15 m) of trees in pineapple, corn, rice, sugarcane farms; and c) mini-forest within farms or set-aside farm parcels for wood trees. Tree integration in the agricultural landscape provides the following benefits: 1) it eliminates the demerits of bare soil-no photosynthesis/no CO₂-fixation, soil erosion, nutrient/water lost; 2) it makes CO₂ sequestration turn-over-significantly longer as tree-cutting cycle is definitely longer than food or cash crops. Annual crops have less than a year CO₂-cycle while trees generally have 10 to 50 years depending on the species and intended use; and 3) it positively influences the hydrologic cycle (Paningbatan 1994) as shown in the following equation:

\[ P = I + R + AS + D + \int Edt \]

where \( P \) = precipitation, \( I \) = infiltration, \( D \) = deep drainage, \( E \) = evapotranspiration, \( R \) = surface run off, \( S \) = soil water storage, A - area, S - integral sign, and dt - derivative sign.

Trees promote I, D, E and S and they decrease R. With this positive impact on microclimate and improve soil water storage (S), there is optimum growth for short-maturing or low-statured and shallow-rooted crops. This contributes to higher CO₂-sequestration in both the aboveground (biomass) and underground (soil) landscapes. Trees may shade the lower-statured crops but pruning excess branches can minimize their shading effects.

Multi-species planting is perceived as one practical option (Hensleigh & Holaway 1988). Multi-storey

![Figure 5. Interactive (additive) effects of crop residue burning in relation to greenhouse gases loading into the atmosphere](image-url)
cropping under coconut is a dominant cropping system at Cavite and Batangas, Philippines. Incidentally, this is not widely adopted in the other coconut-growing provinces of the country (Cosico 1984).

Crop rotation/intercropping. This ensures that different species, especially insects, have access to different host crops, allowing for natural balance of pests and predators, keeping pest problems to the minimum.

Leads to seasonal photosynthesis

Zero crop photosynthesis during non-crop period except if weeds grow profusely

Leads to bare soil

Leads to greater tillage/cultivation to establish the crop or control weeds

Increases need for chemical fertilizer

Increases vulnerability to pests

Fast turnover of CO₂ loading/absorbing

No net CO₂ sequestration

Soil surface heating leading to nutrient/water loss

Release soil C into landscape

CO₂ loading into the atmosphere

Higher agro-chemical usage leads to burning of more fossil fuel

Figure 6. Pathways whereby monocropping leads or contributes to CO₂-GHG loading in the atmosphere

Landscape designed integrated farming (LDIF). An example of an LDIF system is a farm where crop, livestock and aquaculture activities are carried out simultaneously, where, say, crop refuse is fed to swine and the manure goes into the pond for the fish to thrive.

Materials & Methods

The decreased CO₂-loading and the CO₂-sequestering impacts of some agricultural practices in the agricultural landscape were estimated. The method of estimation varied with the practice.

Green manuring. The physical land areas in various Philippine agroecosystems where green manuring can be feasibly incorporated are shown (Table 1). Four agroecosystems are included, namely: rice, corn, coconut, and upland mixed ecosystems. The base areas and the various technical coefficients in the estimate are all listed. Two CO₂-GHG-reducing impacts of green manuring can be seen: 1) the decrease of CO₂ load due to biological N-fixation, the decrease coming in the form of reduced fossil fuel burning (hence CO₂ emission) due to N-fertilizer savings, and 2) the CO₂ sequestration in soils since biomass becomes stable humus-C upon decomposition (15% rice and corn as the biomass is plowed under and only 10% in coconut because biomass stays on the surface). (The other benefits listed in Box 2 are not shown.)

Use of crop residues for mulching or composting. Crop residue biomass in the Philippines have been estimated (Mendoza & Samson 2001) (Table 2). Organic residues can be used as mulch or as source of C-rich material for composting and later on to be used as organic fertilizer. Once applied in the soil, they can form humus-stable C. (In estimating the CO₂-GHG-reducing impacts of utilizing crop residues for mulching and composting, the following technical assumptions have been used: (a) only 50% are used either for mulch or compost, (b) crop residues contain 40% C; (c) 15% is retained as stable humus-C in the soil (Batjes 1999).
Multi-species/tree-integration in the agricultural landscape

In estimating the impacts of tree-integration in the agricultural landscape in terms of CO$_2$-sequestration, two (2) possibilities are considered: perimeter/boundary planting of farmlots, and sparse planting of wood + fruit trees within farmlots. The technical assumptions used in the estimate are shown in Table 2 and are summarized as follows: Ricelands 641 M trees; coconut lands 850 m trees; upland mixed farms 1,300 M trees; total 2,791 M trees.

It is assumed that there are about 1,000 big trees/ha in a primary forest. Hence, tree-integration in the Philippine agricultural (open) landscape is equivalent to about 2.8 Mha of primary forests. Brown et al (1991) estimate the biomass of tropical forest on the basis of data from many tropical countries at 350 t/ha of aboveground biomass prior to human incursion. For the purpose of our estimate, only 30% of the biomass (as reported by Brown et al 1991) is used.

RESULTS

Green manuring can decrease CO$_2$-GHG load in the atmosphere from 1.35-2.96 Mt/year in the 4 agroecosystems considered (Table 3). The potential decrease is highest in the upland mixed agroecosystem at 1.94 Mt CO$_2$/year mainly due to the large area involved. The total soil-sequestered CO$_2$ through green manuring is 2.38-4.44 Mt/year. Likewise, upland mixed shows higher sequestered CO$_2$ due to the larger area (3.0 Mha) involved. As a whole, the total reduction of CO$_2$ loaded in the atmosphere ranged from 4.59 to 9.12 Mt/year. It should be pointed out that these reductions of GHG-CO$_2$ loaded in the atmosphere include only those that can be directly estimated through 1) the biologically fixed N via the legumes which would have otherwise loaded 0.7 kg CO$_2$/kg N if N is manufactured using fossil fuel oil (Nebel & Wright 1996, Rubin et al 1992), and 2) the soil-sequestered CO$_2$ through the given manure crop biomass which when decomposed 15% forms stable humus-C.

The indirect benefits of green manuring in decreasing CO$_2$-GHG emissions as in reduced time and energy in land preparation and pumping water for irrigation due to improve soil physical condition are not included. This is because, in practice, farmers will be doing other nutrient management practices in addition to green manuring to achieve the desired result in farming, which is high yield.

Table 3 shows the estimated weight of crop residues in the Philippines (Mendoza & Samson 2001). About 36.1 Mt of crop residues is produced yearly. About 60% of this is simply burnt for quick and easy disposal except for bagasse, which is used largely as boiler fuel in sugar mills. About 87% of energy used in sugar milling comes from bagasse (Corpuz & Aguilar 1992). In a related study (Mendoza et al 2000), crop residues has been assessed as providing more benefits if used as mulch or as source of

<table>
<thead>
<tr>
<th>AGROECOSYSTEM</th>
<th>TECHNICAL COEFFICIENT BY AGROECOSYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricelands</td>
<td>-1.5 M ha of the 3.0 M ha ricelands can easily implement green manuring</td>
</tr>
<tr>
<td></td>
<td>40-60 kg N/ha is fixed through BNF (Watanabe 1978)</td>
</tr>
<tr>
<td></td>
<td>N is 2% in plant biomass</td>
</tr>
<tr>
<td></td>
<td>15% of plant biomass become stable humus-C upon decomposition, thus, soil CO2 is sequestered (Batjes 1999)</td>
</tr>
<tr>
<td></td>
<td>1 kg N - 10.77 kg CO2 evolved if manufactured (Nebel &amp; Wright 1996, Rubin et al 1992)</td>
</tr>
<tr>
<td>Corn</td>
<td>1.5M ha of the 3.0M corn lands can implement green manuring</td>
</tr>
<tr>
<td></td>
<td>30-50 kg N/ha is fixed by the green manure crops</td>
</tr>
<tr>
<td></td>
<td>15% plant biomass become stable humus-C upon decomposition (Batjes 1999)</td>
</tr>
<tr>
<td>Coconut</td>
<td>Only 40% (1.2 M ha) of the 3.0 M ha coconut lands can adopt green manuring as others prefer multi-storey cropping</td>
</tr>
<tr>
<td></td>
<td>30-60 kg N/ha is fixed through the legume cover crops</td>
</tr>
<tr>
<td></td>
<td>Only 10% of plant biomass becomes stable humus-C upon decomposition because biomass is used as surface mulch and not soil incorporated</td>
</tr>
<tr>
<td>Upland areas</td>
<td>20-60 kg N/ha is fixed by the MPTL</td>
</tr>
<tr>
<td></td>
<td>10% of plant biomass becomes stable humus-C upon decomposition</td>
</tr>
</tbody>
</table>

Common Coefficient : 0.72 kg CO$_2$ evolved
material, more N can be saved from chemical manufacture. N fixation occurs while crop residues (ie, sugarcane trash) are decomposing in the field (Boddey et al 1995, Patriquin 1992). The equivalent CO₂ evolved if this N is manufactured using fossil fuel energy amounts to 1.2 Mt. Hence, if the CO₂-evolved through N-fixed via the decomposition of crop residues, the total CO₂-GHG reduction is 10.96 Mt.

As shown in Table 2, tree integration in various agroecosystems yields 2,791 M trees in rice lands, 850 M trees in coconut lands, and 1,300 M trees in upland mixed farms. At 1,000 big trees/ha in primary forest (Brown et al 1991) the tree integration in various agroecosystems provides an equivalent of 2.8 Mha primary forests. These trees will be sequestering 12.85 Mt of CO₂/year as shown in the estimates below:

<table>
<thead>
<tr>
<th>Area</th>
<th>Green manuring</th>
<th>Mulching/Composting</th>
<th>Tree integration</th>
<th>Total CO₂-GHG reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice lands</td>
<td>4.59 – 9.12 Mt</td>
<td>11.6 Mt</td>
<td>12.85 Mt</td>
<td>39.9 Mt</td>
</tr>
<tr>
<td>Coconut lands</td>
<td>3.2 M (ha area)</td>
<td>1.0 M (average farm size)</td>
<td>700 trees/ha</td>
<td>10.2 Mt</td>
</tr>
<tr>
<td>Uplands</td>
<td>6.5 M (ha)</td>
<td>3.2 M (average farm size)</td>
<td>200 trees/ha</td>
<td>16.2 Mt</td>
</tr>
</tbody>
</table>

These estimates do not include the CO₂ sequestered in the soil due to litterfall and its subsequent decomposition as stable humus-C in the soil. The estimates also exclude the CO₂-sequestration by the annual crops as there is faster CO₂ turnover depending on crop maturity. (For residues used in mulching and composting, their CO₂-sequestration contribution has already been considered in Table 4.)

Annually, the total CO₂-GHG reducing potentials of the 3 agricultural practices assessed are listed below:

- Green manuring : 4.59 – 9.12 Mt
- Mulching/Composting : 11.6 Mt
- Tree integration : 12.85 Mt
- TOTAL : 29.1 – 33.61 Mt

**General Discussion & Implications**

In the tropics (Asia and North Central America), land-use changes from forest to urban and agricultural usages have occurred in widespread areas. The potential for CO₂ sequestration and decreasing CO₂-GHG load in the atmosphere of these forest areas are enormous. It is obvious that we cannot go back to pre-historic times. On the optimistic side, it has been shown that there are a number of agricultural practices that can combine the goals of producing food, fiber and fuel and the need to decrease CO₂-GHG emissions to the atmosphere. Moreover, as evidently shown in the estimates, the agricultural landscape can become a net CO₂-sequestering area as the oceans and forests are (Lasco & Pulhin 1998, Kauppi et al 1992, Quay et al 1992). On a yearly basis, the total CO₂-GHG-reducing potentials of the three agricultural practices (green manuring, mulching/composting and tree integration in the

**Table 2** Technical assumptions used in estimating the impacts of tree-integration on CO₂ sequestration in the Philippine agricultural Landscape.

<table>
<thead>
<tr>
<th>A. RICELANDS</th>
<th>B. COCONUT LANDS</th>
<th>C. UPLANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.33 M trees</td>
<td>3.2 M (ha)</td>
<td>6.5 M (ha)</td>
</tr>
<tr>
<td>1,000 trees/ha</td>
<td>1,000 trees/ha</td>
<td>1,000 trees/ha</td>
</tr>
<tr>
<td>10.2 Mt</td>
<td>10.2 Mt</td>
<td>10.2 Mt</td>
</tr>
<tr>
<td>0.64 M ha of primary forest</td>
<td>0.64 M ha of primary forest</td>
<td>0.64 M ha of primary forest</td>
</tr>
<tr>
<td>228 trees/ha</td>
<td>228 trees/ha</td>
<td>228 trees/ha</td>
</tr>
</tbody>
</table>

These estimates do not include the CO₂ sequestered in the soil due to litterfall and its subsequent decomposition as stable humus-C in the soil. The estimates also exclude the CO₂-sequestration by the annual crops as there is faster CO₂ turnover depending on crop maturity. (For residues used in mulching and composting, their CO₂-sequestration contribution has already been considered in Table 4.)
agricultural landscape) of about 33 Mt CO2 yearly is sufficient to offset the equivalent of CO2 emission of deforestation in the last 80 years estimated at 2.7 Bt of CO2 (Lasso 1998).

The adaptive agricultural systems in this new millennium should mitigate the ecological greenhouse gas II global warming II global climate-change problems while still producing more food, feed, fiber and fuel for the world. Shown in Figure 7 are the summarized features of CO2-GHG-reducing agricultural systems. Short of sounding prescriptive but rather pro-creative, there should be no doubt that the 21st century agriculture should have these features.

As pointed out earlier, the CO2-GHG contribution of agriculture appeared small in the total estimates. This happened because the CO2 - GHG estimates considered only the primary aspects of production. There is no disagreement to this approach. But to effectively reduce CO2-GHG emission, a “food system” conceptual framework for auditing CO2-GHG should be considered. This leads to the two (2) fundamentally allied options in

**Table 3. Reduction of CO2 loaded in the atmosphere and soil sequestered CO2 through green manuring**

<table>
<thead>
<tr>
<th>AGRO-ECOSYSTEM</th>
<th>AREA USED FOR ESTIMATE (M ha)</th>
<th>RATING</th>
<th>DECREASED CO2 LOAD DUE TO FIXATION (A) (M tonnes)</th>
<th>SOIL SEQUESTERED CO2 (B) (M tonnes)</th>
<th>TOTAL (A+B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>1.5</td>
<td>Low</td>
<td>0.65</td>
<td>0.66</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>0.90</td>
<td>0.99</td>
<td>1.89</td>
</tr>
<tr>
<td>Corn</td>
<td>1.5</td>
<td>Low</td>
<td>0.48</td>
<td>0.64</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>0.81</td>
<td>1.10</td>
<td>1.91</td>
</tr>
<tr>
<td>Coconut</td>
<td>1.2</td>
<td>Low</td>
<td>0.39</td>
<td>0.26</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>1.03</td>
<td>0.70</td>
<td>1.73</td>
</tr>
<tr>
<td>Upland Mixed</td>
<td>3.0</td>
<td>Low</td>
<td>0.65</td>
<td>0.82</td>
<td>1.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>1.94</td>
<td>1.65</td>
<td>3.59</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>Low</td>
<td>2.17</td>
<td>2.38</td>
<td>4.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4.68</td>
<td>4.44</td>
<td>9.12</td>
</tr>
</tbody>
</table>

Technical coefficients used in the computations are shown in Table 1.

As pointed out earlier, the CO2-GHG contribution of agriculture appeared small in the total estimates. This happened because the CO2 - GHG estimates considered only the primary aspects of production. There is no disagreement to this approach. But to effectively reduce CO2-GHG emission, a “food system” conceptual framework for auditing CO2-GHG should be considered. This leads to the two (2) fundamentally allied options in

**Table 4. Estimated crop residue biomass in the Philippines that are available for mulching or composting (Mendoza and Samson, 2001)**

<table>
<thead>
<tr>
<th>CROP RESIDUES</th>
<th>AMOUNT (1,000 mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice straw</td>
<td>11,400</td>
</tr>
<tr>
<td>Rice hull</td>
<td>1,807</td>
</tr>
<tr>
<td>Peanut hay</td>
<td>150</td>
</tr>
<tr>
<td>Sugarcane trash</td>
<td>3,700</td>
</tr>
<tr>
<td>Bagasse</td>
<td>6,000</td>
</tr>
<tr>
<td>Mudpress</td>
<td>505</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>962</td>
</tr>
<tr>
<td>Corn husks</td>
<td>418</td>
</tr>
<tr>
<td>Corn stover</td>
<td>4,186</td>
</tr>
<tr>
<td>Coconut husks</td>
<td>3,393</td>
</tr>
<tr>
<td>Coconut frond</td>
<td>3,554</td>
</tr>
<tr>
<td>TOTAL</td>
<td>36,075</td>
</tr>
</tbody>
</table>

Total C - content of crop residues - 14.43 Mt

*Crop residues contain 40% C.*

the agricultural systems advocacy in the new millennium. These are as follows:

- localized food production
- consuming food lowest in the food chain

Localized food production shall significantly reduce the energy cost in transport, processing, storage of food products. Localized food production also implies that each individual try to produce/grow her/his own food. This means finding time and space to grow crops. The humid tropics like the Philippines is so an accommodating environment for this kind of human activity. There is plenty of sunshine and moisture to support crop growth and development. Home gardening and edible landscaping are not new concepts or ideas. They need to be revisited and re-appreciated in this millennium to ensure food supply availability.

It is a difficult advocacy activity because people are now so engrossed on their work and most people have no farming exposures. Thus, it is difficult for them to begin growing their own food crops. On the one hand, this hypothesis may be right but it can also be wrong as many urban-bred people also are plant lovers. With proper information they can easily shift their attention from ornamentals to food crops or vegetables culture.

The other advocacy aspect of organic agriculture as a movement which is directly related to the current effort of reducing CO2-GHG emission is consuming food lowest in the food chain.

In practice, this means a shift to a vegetarian diet. A meat-based diet, while it maybe rich in protein-amino acids, and it is one of the major agricultural activity contributing to high CO2-GHG in the atmosphere.

- Consider the inefficient conversion of energy of plant protein (soybean) fed to animals and huge
fossil fuel oil based energy inputs utilized in growing corn.

- Greater bulk of the corn and soybean in the North is merely fed to livestock (swine, poultry and even for cattle fattening in the feed lot). This is not to mention the added cost in health care due to the lifestyle-associated illness (high fatty acids, cholesterol-bearing foods).

A successful shift to vegetarian diet also mean growing mostly the food (vegetables) that ones prefer to eat. This is also localizing food production. In the North, however, a vegetarian diet does not necessarily mean a reduction in CO2-GHG emission due to the long distance travel of food to reach the consumer during wintertime. In the tropics, where water is available, continuous production is possible. Furthermore, there are several perennial vegetables, which can be grown the whole year round (horse raddish, sesbania, cassava, sweet potato, alugbati, saluyot, niyog niyugan, etc.).

The aggregate impacts in terms of CO2-GHG emission reduction of the two advocacy if adopted can be gleaned on:

- It makes house refrigerator obsolete. There is no more need for refrigerator for your kitchen gardens supplies natural fresh foods. This reduces the electricity consumption (100-200 kw/mo).
- Many vegetables could be eaten raw or if they are cooked, they require minimal boiling or heating. Thus, less energy is spent in cooking (10-15 LPG/household/mo).

The other equally if not more important impact of a vegetarian diet is that 20 times more people could eat. This could be the readily solution to the growing food requirements of the burgeoning size of human population especially in the coming millenium. It is important to point out that our current agricultural or food systems are also contributing tremendous amount of CO2-GHG in the atmosphere. Increasing CO2-GHG in the atmosphere is propelling global warming or global climate change which constitute one significant threat to our ability to produce more food (Mendoza 2001).

### CONCLUSION

The CO2-GHG contribution of agriculture can be significantly reduced. This could be done by adopting ecological agriculture practices such as green manuring, mulching, the use of compost, and tree integration in the agricultural landscape. Also, reduced tillage and no burning of crop residues are practices that can also contribute in the reduction of CO2 - GHG emission into the atmosphere.

Tree integration in the agricultural landscape is shown to have the highest impact in mitigating the CO2-GHG emission into the atmosphere as trees sequester CO2 longer in their biomass. This requires a re-designing of our current highly specialized and monocropped systems of agricultural crop production.

Likewise, it is necessary to pursue a localized, small scale and family based systems of food production to avoid the fossil fuel-based energy used in the transport, processing and storage of food. On the consumption side, eating food lower in the food chain and consuming freshly gathered food rather than refrigerated and processed foods can significantly reduce CO2-GHG load in the atmosphere. A food systems accounting of the associated CO2 emission into the production, processing, storage, transport and/ or distribution of food is necessary to determine the precise contribution of the food we eat in the emission of green house gases causing global warming and climate change.

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Figure 7. Summarized features of carbon dioxide greenhouse gas-reducing agricultural systems

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