THE EX ANTE CARBON-BALANCE TOOL

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# The Low Carbon Agricultural Support Project (LCASP) in Vietnam

## Carbon balance appraisal with the Ex-Ante Carbon balance Tool

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by

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**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**

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# ABBREVIATIONS

| | |
|---|---|
| ADB | Asian Development Bank |
| AFOLU | Agriculture, Forest and Other Land Use |
| BP | Biogas Plant |
| C | Carbon |
| CC | Climate Change |
| CDM | Clean Development Mechanism |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| CSTR | Continuous Stirred Tank Reactor |
| DM | Dry Matter |
| EX-ACT | EX-Ante Carbon-balance Tool |
| FAO | Food and Agriculture Organisation of the United Nations |
| GHG | Green House Gas |
| GWP | Global Warming Potential |
| IPCC | Intergovernmental Panel on Climate Change |
| LAC | Low Activity Clay |
| LBP | Large Biogas Plant |
| LCASP | Low Carbon Agricultural Support Project |
| MBP | Medium Biogas Plant |
| Mt | Million metric tons |
| $N_2O$ | Nitrous Oxide |
| SBP | Small Biogas Plant |
| $tCO_2$-e | Ton of $CO_2$ equivalent |
| UNFCCC | United Nations Framework Convention on Climate Change |

# 1 Summary

The present study is a first appraisal of the mitigation potential of the Low Carbon Agricultural Support Project (LCASP) in Vietnam, financed by the Asian Development Bank (ADB). The project, starting in 2013, will support the development of biogas plants in the country, as well as enhance the adoption of Climate Smart Agriculture (CSA) practices within smallholders.

The results highlight the mitigation potential of the project, which avoids the emissions of almost 25 $MtCO_2$-e during a 20 year-period. While the anaerobic digestion of manure in biogas plants contributes by 15% to the mitigation, the main benefits clearly come from the switch towards more sustainable agronomic and management practices.

The results should only been considered as an estimation, and a more detailed analysis could be conducted, especially once the final decision on the participating provinces and the number of biogas plant is set up.

# 2 Introduction

**Objective:** This paper identifies and interprets the main project impacts on climate change mitigation. It shows the results issued from a real case project, although simplified.

**Target audience**: This module targets current or future practitioners in formulation and analysis of investment projects or on climate change issues, as well as people working in public administrations, NGO's, professional organizations or consulting firms. Academics can also find this material useful to support their courses in carbon balance analysis and development economics.

**Required background**: In order to fully understand the content of this module the user must be familiar with:

- Concepts of climate change mitigation and adaptation
- Concepts of land use planning and management
- Elements of project economic analysis

Readers can follow links included in the text to other EASYPol modules or references[1]. See also the list of EASYPol links included at the end of this module.



[1] EASYPol hyperlinks are shown in blue, as follows:

a) training paths are shown in **underlined bold font**
b) other EASYPol modules or complementary EASYPol materials are in ***bold underlined italics***;
c) links to the glossary are in **bold**; and
d) external links are in *italics*.

# 3 Context of the Carbon Balance Appraisal

The following work presents a tentative carbon balance appraisal of the LCASP project in Vietnam, using the EX-ACT tool. It must be considered as a first draft analysis, to show project managers of the Asian Development Bank (ADB) the potentialities of the EX-ACT tool and to trigger interest to pursue a more detailed analysis.

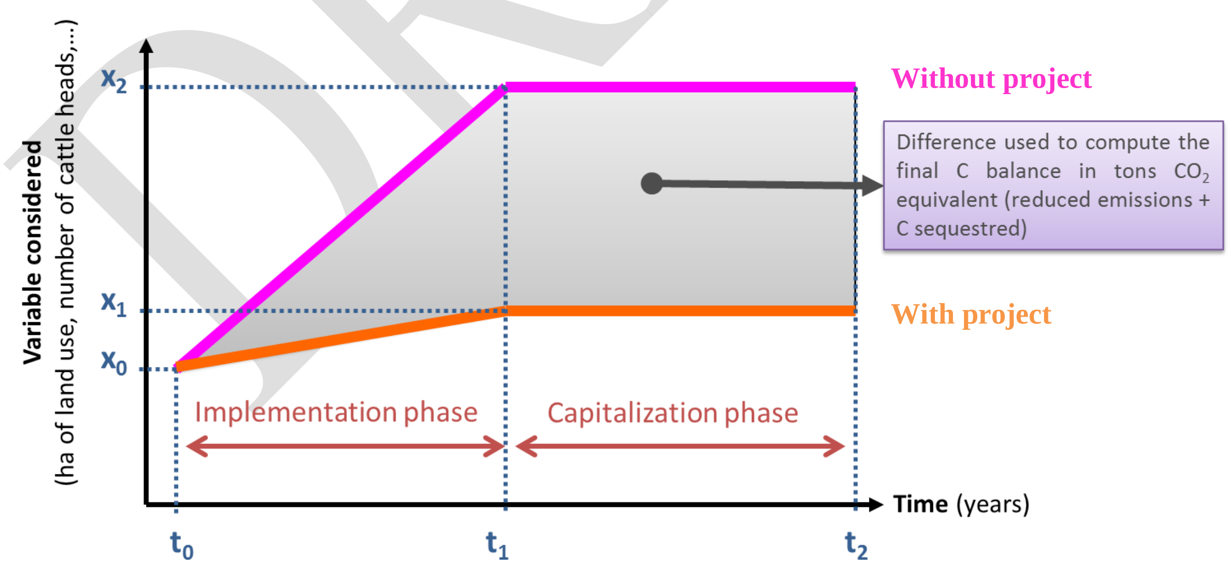
## 3.1 The EX-Ante Carbon balance Tool (EX-ACT)

EX-ACT is a tool developed by FAO and aimed at providing ex-ante estimates of the impact of agriculture and forestry development projects on GHG emissions and C sequestration, indicating its effects on the C-balance[2], which is selected as an indicator of the mitigation potential of the project. It is capable of covering the range of projects relevant for the land use, land use change and forestry (LULUCF) sector. It can compute the C-balance by comparing two scenarios: "without project" (i.e. the "Business As Usual" or "Baseline") and "with project". Main output of the tool consists of the C-balance resulting from the difference between these two alternative scenarios (Figure 1).

The model takes into account both the implementation phase of the project (i.e. the active phase of the project commonly corresponding to the investment phase), and the so called "capitalization phase" (i.e. a period where project benefits are still occurring as a consequence of the activities performed during the implementation phase). Usually, the sum of the implementation and capitalization phases is set at 20 years, since scientists estimate that after this period, the soil reaches its equilibrium, therefore there is no variation in the carbon content of the soil anymore. EX-ACT was designed to work at a project level but it can easily be up-scaled at program/sector or national level.



Figure 1: Quantifying C-balance "with" and "without project" using EX-ACT




*Source: Bernoux et al. 2010*

[2] C-balance = GHG emissions - C sequestered above and below ground.

EX-ACT measures C stocks and stock changes per unit of land, as well as Methane ($CH_4$) and Nitrous Oxide ($N_2O$) emissions expressing its results in ton of Carbon Dioxide equivalent per hectare (t $CO_2$-e/ha) and in ton of Carbon Dioxide equivalent per year (t $CO_2$-e/yr).

Emissions factors and carbon storage coefficients are needed to convert land use changes and agronomic practices into GHG emissions. The EX-ACT tool includes default coefficients (Tier 1 approach) taken from the Intergovernmental Panel on Climate Change (IPCC) Guidelines 2006, but in some cases, local data can be used to be more specific to the local context (Tier 2 approach).

## 3.2 Country background

In Viet Nam, agriculture's share of GDP (20%) is declining, but output is expanding and the sector remains a key contributor to exports (25%) and employment (70% of rural households). Although for many people agriculture is becoming an increasingly part-time activity, the sector continues to provide a safety net for rural Viet Nam. Sector output composition is mixed, but production remains dominated by rice. Between 1990 and 2008 the area under rice cultivation grew by about 20%, but national production almost doubled. In addition to the 6.6 million ha devoted to rice, over 3 million ha are under perennial crops (coffee, tea, rubber, cashews, sugarcane, cotton, pepper), and over 2.1 million ha are under annual crops (maize, sweet potatoes, soybean, peanuts). Farm incomes are often supplemented by livestock production which may make up a large part of household incomes. Forestry accounts for only around 1% of GDP, although it plays a crucial role in environmental stability and ecological sustainability. Fisheries constitute about 4% of GDP with aquaculture production by the private sector growing rapidly. Agriculture trade growth has been substantial, but remains dominated by commodities such as rice, pepper, coffee and aquaculture products.

Several environmental problems have emerged within the agricultural and forestry sector. After the energy sector, agriculture is the second largest contributor to greenhouse gasses in Viet Nam, with 43% of the total national emissions. Over 40% of arable land is degraded, because of heavy use of inorganic fertilizers and other unsustainable agricultural practices. The conversion of land to urban and industrial uses further reduces limited arable land (28% of total) and contributes to the small average farm sizes. Deforestation has been continuously increasing since about 56% of Vietnamese still rely on the unsustainable harvest of firewood for their household energy needs. The use of firewood for cooking creates indoor pollution, causing serious respiratory diseases, especially among rural women and children. GHG emissions from the burning of biomass in open fields are also significant.



## 3.3 Description of the LCASP project

The proposed project will strengthen policies and institutions to promote climate smart agriculture (CSA) practices; establish infrastructure for livestock waste management; and, enhance technology and development transfer on CSA practices. These will be parts of climate change (CC) mitigation and adaptation measures to reduce green house gas (GHG) emission in 16 provinces of Viet Nam (see Table 1 for the list of provinces).

The Project will reduce air, water and soil pollution by supporting Climate Smart Agricultural Waste Management Practices (CSAWMP) for treating livestock wastes through the expanded use of biogas and bio-slurry processing technologies.

The project is made of three main components: (i) strengthening CSAWMP policies, regulations and supporting institutions; (ii) expanding livestock waste management infrastructure systems; and, (iii) enhancing CSAWMP knowledge and technology development and transfer systems.

The project is estimated to cost $143.55 million, financed by the Asian Development Bank.

Within the first component, the proposed activities are as follow: (i) assess and reform proper laws/ decrees/regulations/guidelines on biogas and its value chains management; (ii) empower the government staff and other key stakeholders on technical, management and financial management of biogas and its value chains; and (iii) facilitate shifting to commercial approaches to sustain biogas development.

Regarding the second component, i.e. expanding livestock waste management infrastructure systems, the following are key investment activities to support various infrastructures for biogas plants (BP) and their supporting facilities: (i) prepare detailed engineering design and management plans for BPs and their supporting facilities; (ii) construct BPs and supporting infrastructure for the BP's value chains; and (iii) establish access to carbon markets to sustain biogas development.

To enhance the transfer of CSAWMP based technology and development in the participating provinces, the LCASP project will (i) enhance national and international technology transfer on biogas and other waste management; and (ii) transfer the standardized models for Small Biogas Plants (SBP) based CSAWMP to small livestock farms and other stakeholders.

Only components 2 and 3 will have an impact on the GHG emissions and are therefore analyzed in the present study.

# 4 GHG EMISSIONS AND ABATEMENT OF THE DIFFERENT PROJECT'S ACTIVITIES

## 4.1 Basic parameters of the analysis

In order for the EX-ACT tool to choose the adequate emission factors and coefficients to calculate the carbon balance, we need to define the type of climate, the moisture regime, the dominant type of soil and the duration of the project, both the implementation and the capitalization phases.

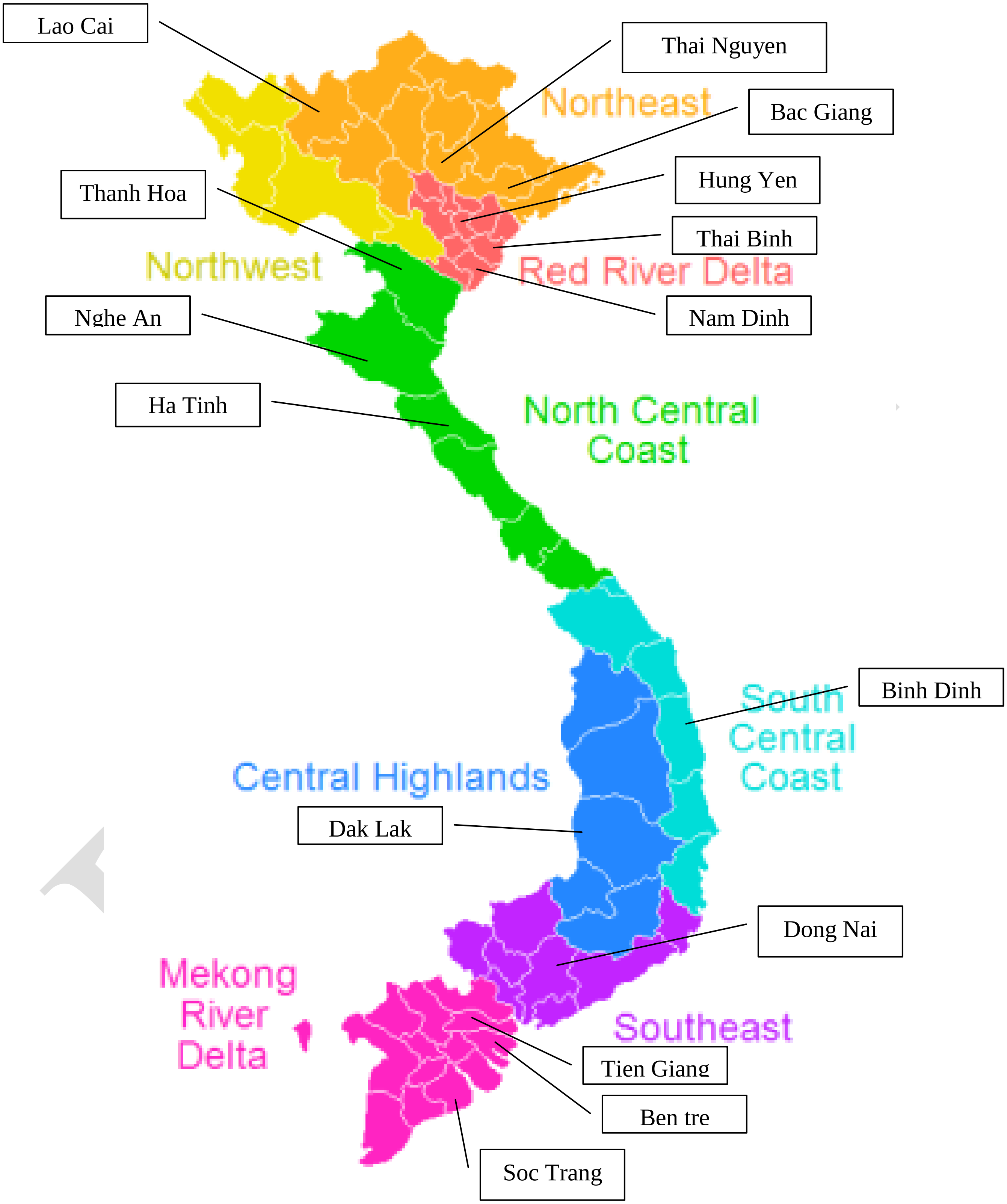
The 16 provinces concerned by the project are presented in Table 1 and Figure 2. However, this list is not definitive and may be reduced to only 10 provinces. But for the present analysis, the 16 provinces of Table 1 have been kept.

Table 1: Provisory list of the provinces concerned by the LCASP project

| Region | Provinces |
|---|---|
| NorthEast | |
| | Lào Cai |

| | |
|---|---|
| | Thái Nguyên |
| | Bắc Giang |
| | Phú Thọ |
| Red River Delta | |
| | Hưng Yên |
| | Thái Bình |
| | Ninh Bình |
| North Central Coast | |
| | Thanh Hoá |
| | Nghệ An |
| | Hà Tĩnh |
| South Central Coast | |
| | Bình Định |
| Central Highland | |
| | Đắk Lắk |
| Southeast | |
| | Đồng Nai |
| Mekong River Delta | |
| | Tiền Giang |
| | Bến Tre |
| | Sóc Trăng |

Figure 2: Localization of the 16 provinces

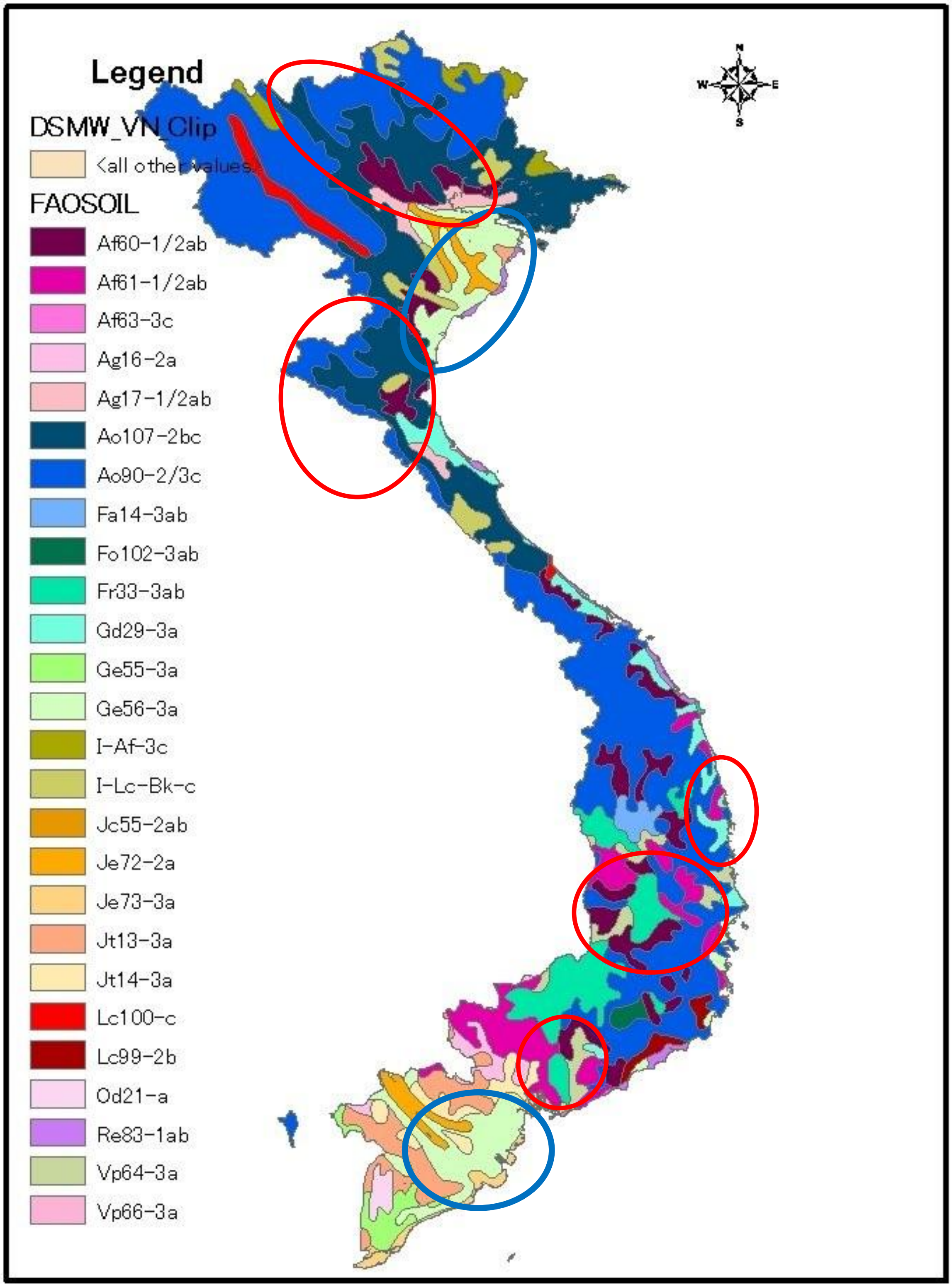



*Source: http://en.wikipedia.org/wiki/File:VietnameseRegions.png*

The average temperature in each provinces is about 22-24 ºC, while the average precipitations run from 1100 to 2400 mm/year. However, the majority of the country has a moist tropical climate; some zones in the North have a tropical wet climate. For the present analysis, we will therefore choose a dominant tropical moist climate. Nonetheless, it will be interesting to undergo sensitivity analysis with a tropical wet and even a tropical mountain climate, since the relief in the north and the inter country is mountainous (chapter 5 Sensitivity analysis).

Regarding the type of soil, Figure 3 below shows that the Red River and Mekong deltas and some parts of Thanh Hoa and Ha Tinh have an eutric gleysol (Ge in the legend), i.e. a wetland soil. The other provinces mainly have rhodic ferralsol (Fr), orthic acrisol (Ao) and ferric acrisol (Af). Such soils are classified as Low Active Clay (LAC) soils. In this first appraisal, to simplify the analysis, we will consider a wetland soil, since 62% of the paddy rice of the 16 provinces is located in the delta provinces (General Statistics Office of Vietnam).

Figure 3: Soil map of Vietnam




*Source: FAO, World soil map*

The project will be implemented from 2013 to 2019; the implementation phase is therefore 6 years, and the capitalization phase 14 years, so that the total duration of analysis is 20 years, corresponding to the average life time of the biogas plants and the soil's equilibrium.

## 4.2 The development of biogas plants

The project will contribute to the achievement of the Vietnamese government's target of 2 million small biogas plants by 2020.

Data about the number, the average size and the type of biogas plant come from the draft final report on the LCASP project of 15th April 2012. The project seeks to have 90% of the plants in use and running without gas leakages. Therefore, we assume that the total number of BP built is 50 040, but that only 45 036 will be really running during the lifetime of the analysis.

Table 2: The different types of biogas plant (BP)

| | Number of plants | | Average size in $m^3$ | Type of technology |
|---|---|---|---|---|
| | Built | Effectively running (90%) | | |
| **Small Biogas Plant (SBP)** | 50,000 | 45,000 | 10 | KT1, KT2, KT31, composite |
| **Medium Biogas Plant (LBP)** | 30 | 27 | 500 | Covered lagoon, stirred covered lagoon, KT31, plug flow, CSTR |
| **Large Biogas Plant (LBP)** | 10 | 9 | 2000 | Covered lagoon, stirred covered lagoon, KT31, plug flow, CSTR |
| **TOTAL** | 50,040 | 45,036 | | |

### 4.2.1 Emissions from the construction of the BP

The KT1/2 and KT31 small biogas plants are made of concrete and bricks, whose production and transport emit GHG. The composite design as well as some parts of the KT31 plant requires a composite material made of synthetic fiberglass, carton fiber glass and polyester. The composite material has to be imported outside of Vietnam, while bricks and concrete can be found locally. To simplify the analysis, we will assume that the 50 000 SBP are of KT1/2 type and therefore only concrete is necessary for their construction. The limited amount of macadam is not taken into account in this first analysis (see Table 3). Regarding MBP and LBP, the typical type will be a covered lagoon; it requires High Density PolyEthylene (HDPE) layers at the bottom and at the top, for water and air tightness. It has been estimated that for a 500$m^3$ MBP, 232$m^2$ of HDPE will be needed and 585$m^2$ for a 2,000$m^3$ LBP. Classic HDPE geo-membranes have a thickness of 1.5 mm.

Table 3: Materials needed for the construction of the biogas plants

| | Cement in kg | Brick in unit | Sand in $m^3$ | Macadam in $m^3$ | Steel in kg | HDPE in $m^2$ |
|---|---|---|---|---|---|---|
| **KT1** | 880 | 1410 | 1.9 | 0.9 | 11 | |
| **KT2** | 1290 | 2790 | 2.5 | 1.8 | 16 | |
| **Medium covered lagoon** | | | | | | 232 |
| **Large covered lagoon** | | | | | | 585 |
| **Average** | 1085 | 2100 | 2.2 | 1.35 | 13.5 | / |
| **GHG emissions** | 1.98 t CO2-e/t | 0.3 t CO2-e/1000 bricks | 0.008 t CO2-e/$m^3$ | | 0.238 (rolling steel) t CO2-e/t | 0.003 t CO2-e/$m^2$ |

*Source: Sustainable Energy Development Consultancy Joint Stock Company, April 2010, p.14-15 for the quantity of each material*

*Ministry of natural resources and environment of Vietnam, November 2005 for the emission factors of cement, brick and steel*

*ICE 2008 and http://www.simetric.co.uk/si_materials.htm for the emission factor of sand and the density of dry sand*

*ICE 2008 and CETCO 2011 for the emission factor of HDPE and its density*

**The total GHG emissions from the construction of BP are 139,779 t CO2-e**. 77% of these emissions are due to the use of cement for the SBP.

Transport would represent a significant source of GHG emissions. Materials for SBP, i.e. cement, sand, bricks, are locally available, probably with distance transport less than 50km, but composite and HDPE need to be imported by air, ship and/or road. Furthermore, the disposal of excavated soil in landfill or somewhere else would also result in GHG emissions. However, due to the complexity of such analysis, transport has not been accounted for in this first analysis.

### 4.2.2 Emissions from manure avoided thanks to the anaerobic digestion

The anaerobic digestion of manure prevents methane and nitrous oxide emissions from manure management. According to the biogas survey 2010-2011, the main type of feed injected into the digester is pig dung (98%), followed by other type of feed (65% - human dejection, plants), poultry waste (15%) and cattle manure (13%). To simplify the analysis, we will consider that all the BP are fed with pig dung. In their technical review, the Sustainable Energy Development Consultancy Joint Stock Company states that a biogas plant needs about 10-12kg of pig dung per cubic meter of digester per day. For a 10$m^3$ SBP, this corresponds to 40 t of pig dung per year. . This estimation is close to the one given for a 10$m^3$ Puxin Digester (Chinese company): 700kg of manure four days after the construction of the plant, and 30 days after start-up, approximately 200-250kg of slurry (50% manure/organic material and 50% water) on a daily basis. So in total, the amount of manure is 42t per year.

(700+125*(365-4-30)).Since one pig produces on average 3 kg of dung per day[3], a 10m3 SBP digest the annual dejections of about 37 pigs.

For this first assessment, we will also consider that covered lagoon, i.e MBP and LBP need 11kg of pig dung/$m^3$ of digester/day. A more precise analysis could be done once we have more details on the feeding material needed for each type of biogas plant.

Table 4 shows the dung equivalent in terms of pigs' number. The calculations are based on 90% plants in use.

Table 4: Number of pigs whose dejections are anaerobically treated

| | For one biogas plant | | For 45 036 BP |
|---|---|---|---|
| | Quantity of dung for the digester's size in t/year | Equivalent in terms of animals (in head) | Equivalent in terms of animals (in head) |
| **SBP** | 40 | 37 | 1 650 000 |
| **MBP** | 2008 | 1 833 | 49 500 |
| **LBP** | 8030 | 7 333 | 66 000 |
| **Total** | **10 078** | **9 203** | **1 765 500** |

EX-ACT can calculate these avoided emissions if we add 1 765 500 market swine in the "without" scenario. However, we have to use an emission factor of 0 for the enteric fermentation since only the emissions from manure management are concerned.

**By treating the pig dung under anaerobic conditions and by collecting the biogas produced, it avoids the emissions of 3 898 568 tCO2-e.**

A quick study where the digester is fed with 51% of pig dung, 7% of cattle waste, 8% of poultry dung and 34% with other waste (figures from the biogas survey 2010-2011) shows that the annual dejections of 19 pigs, 1 cow and 108 poultry are needed for a SBP. As a result, **the anaerobic digestion of pig, cattle and poultry dung avoids the emissions of 2 292 258 tCO2-e during the 20 years of analysis**. It is 0.6 times less than the previous result, where only pig dung has been taken into account, but it seems to be a more realistic figure that we will kept in the final carbon balance.

### 4.2.3 Emissions savings thanks to energy substitution

The biogas produced by SBP will mainly be used by households for cooking and lighting. The energy from the biogas (composed on average of 60% methane and 40% carbon dioxide) will replace coal, LPG, electricity, kerosene, wood and agriculture residues. Figures are given in the LCASP draft final report (15th April 2012); nonetheless, we can question their accuracy and reliability. Indeed, it is not clear whether the figures given p.4 of the financial analysis have to be summed up or taken separately (e.g., 1 SBP provides the same amount of energy as 9 734 kg of coal OR the same amount as 40.5 kg of LPG + 9 734 kg of coal + 2 623 kg of wood + 665 kg of agricultural residues). Moreover, the revenue given in US dollar (155.86 $/yr) does not correspond to the cost per unit multiply by the quantity of

[3] http://www.infonet-biovision.org/default/ct/602/products

energy saved. Furthermore, the figures of the financial analysis are quite different from thus of the Sustainable Energy Development Consultancy Joint Stock Company in their evaluation study of April 2010, and the total energy saving differs from a factor 10 (see Table 5). It seems that the data of this last report are more reliable, since the total energy savings of 20 GJ/year is close to the energy content of the biogas produced annually by a 10 $m^3$ digester (0.3 $m^3$ biogas/$m^3$ of digester/day, with an energy content of 6kWh/$m^3$ biogas, i.e. 0.0216 GJ/$m^3$ biogas, means that a 10$m^3$ digester produce the equivalent of 24 GJ/year (0.3 * 10 * 365 * 0.0216)). Therefore, we will use these data to estimate the GHG abatement of energy substitution.

Table 5: Energy substitution for the SBP

| Energy substitution per year and per SBP | LCASP report (financial analysis, p.4) | Sustainable Energy Development Consultancy Joint Stock Company, Evaluation study for household biogas plant models, p.45<br>Average for the KT1 and KT2 plants | Energy content in GJ/t (except for electricity, in GJ/kWhe) |
|---|---|---|---|
| LPG in kg | 40.5 | 0 | 46 |
| Coal in kg | 9 734 | 258 | 24.5 |
| Kerosene in kg | 0 | 54 | 44 |
| Electricity in kWh | 86 | 0 | 0.0036 |
| Wood in kg | 2623 | 780, including agricultural residues | 14.7 |
| Agricultural residues in kg | 665 | Included in the wood | 14.5 (straw) |
| TOTAL energy in GJ | 289 | 20 | |

*Source: Sustainable Energy Development Consultancy Joint Stock Company, April 2010, p.45*
*Low Carbon Agricultural Support Project, 15th April 2012, summary financial and economic analysis, p.4*
*http://www.motiva.fi/myllarin_tuulivoima/windpower%20web/fr/stat/unitsenv.htm and Ademe, 2005 for the energy content*

By multiplying the GHG emission factor of each type of fuel (either EX-ACT tier 1 coefficient from IPCC or coefficients from Ademe) with the quantity of fuel saved per SBP and the number of SBP running (45 000 SBP, i.e. 90% of the total plants built), the result is a total saving 1,610,040 t CO2-e during the 20 year analysis for the Small Biogas Plant. Nonetheless, it is necessary to add the emissions from the burning of the biogas, which releases carbon dioxide (75 kg CO2-e/GJ, Ademe 2005). These emissions reach 1,357,034 t CO2-e. Therefore, the net savings are only 253,006 t CO2-e during 20 years.

Medium and Large Biogas Plants will generate electricity from the biogas, thanks to a motor burning the biogas, and producing heat and electricity. The efficiency is on average 1.55 kWh/$m^3$ of biogas, according to the economic analysis of the LCASP project (even though the biogas contains a potential energy of 6 kWh/$m^3$, turbine efficiency ranges between 25–40%[4]). Therefore, we need to know the average annual biogas production of MBP and LBP plant. A conservative and official value is 0.3 $m^3$ of biogas produced per $m^3$ of volume digested (CDM 36th meeting), although higher values have been identified for 10$m^3$ KT1 and KT2 plants in Vietnam (0.47 and 0.52 $m^3$ of biogas/$m^3$ of digester). In this

[4] Cuéllar and Webber, 2008

first draft analysis, we will use a ratio of 0.3. Table 6 shows that MBP and LBP produce about 424 MWh of electricity each year, assuming they are running 365 days per year.

Table 6: amount of biogas and electricity produced by medium and large biogas plants

| | Size of the plant in $m^3$ | Biogas produced in $m^3$/plant/yr | Number of plants (90% in use) | Total biogas production in 1000 $m^3$/yr | Total gross energy generated in GJ/yr | Total electricity generated in MWhe/yr |
|---|---|---|---|---|---|---|
| **SBP** | 10 | 1,095 | 45,000 | 49,275.0 | 1,064,340 | / |
| **MBP** | 500 | 54,750 | 27 | 1,478.3 | / | 2,291 |
| **LBP** | 2000 | 219,000 | 9 | 1,971.0 | / | 3,055 |
| **Total** | | | **45,036** | **52,724.3** | **1,064,340** | **5,346** |

About 10% of the electricity generated is used by the plant (type CSTR and stirred lagoon), the rest is injected on the national network. The 90% injected on the grid is counted as a saving in emissions, whereas the 10% are accounted as a net GHG emission since they are consumed by the plant. The average emission factor for the traditional Vietnamese electricity is 0.417 tCO2-e/MWh (EX-ACT, IEA). The electricity is generated mainly from fossil fuels (35% of the Vietnamese electricity comes from hydro-power, 40% from natural gas, 21% from coal and 4% from oil – World Bank, 2008).

50% of the biogas energy content is converted into heat. Some of this heat is either used as process heat for heating the biomass, is lost or is used elsewhere on the plant. Approximately half of the heat produced will be available for other heating purposes (Jørgensen, 2009). We will therefore assume that 25% of the GJ produced by MBP and SBP is available to replace fossil fuels (coal, kerosene), wood and electricity, with a similar repartition between this energy sources as for the SBP.

Such energy substitutions avoid the emissions of 74,738 t $CO_2$-eq during 20 years.

However, the biogas is burned to free its energy; this combustion releases 75 kg $CO_2$-e/GJ (Ademe, 2005), i.e. 94,992 t $CO_2$-e for a 20 year-period.

**Finally, the production of this "green" energy by the biogas plants** enables to **avoid the emissions of 232 752 t CO2-e during 20 years (abatement of 253 006 t CO2-e for the SBP and emissions of 20 254 t for the MBP and LBP).**

Furthermore, the savings in fuel wood could have a positive impact on forest degradation and deforestation. Provinces concerned by the project are covered with either tropical dry forests (South Central Coast and Central Highlands regions), tropical moist deciduous forests (Northeast and North central Coast regions) or mangroves (Red River and Mekong River deltas) (Figure 4). The repartition of each type of forest, presented in

Table 7 derives from Vietnamese statistics and will be used to estimate the GHG savings thanks to a decrease in forest degradation. To be conservative, we have assumed that firewood harvesting degrades the forest (from a low to a large state of degradation), but don't lead alone to its total deforestation.

On average, a mixed broadleaved coppice can produce up to 3t of firewood per ha and per year[5] or 2.5 $m^3$/yr (i.e. 1.8 t with an average wood density of 0.7 $kg/m^3$) (Sourdril et al, 2012). Using a figure of 2t/ha/yr, circa 18 ha of forest is preserved annually thanks to the savings of 36t of firewood per year. **Therefore, the emissions savings from the reduction in forest degradation due to the reduction of firewood needs reach 66 535 t CO2-e during 20 years.**

Figure 4: Dominant type of forests in Vietnam

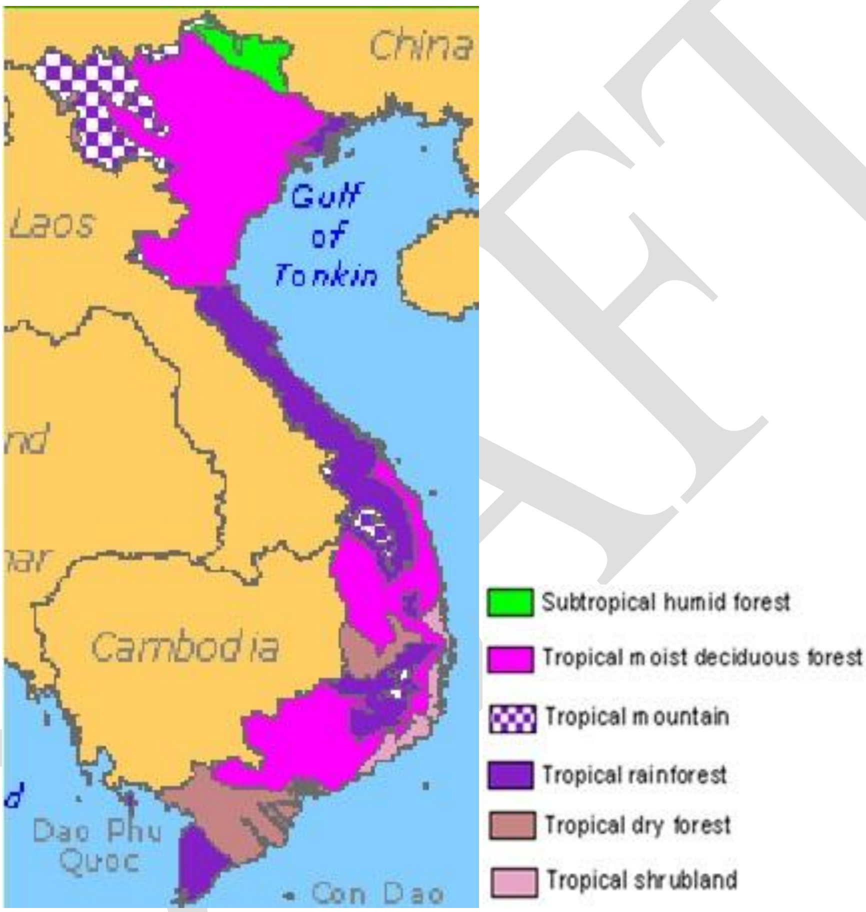





Table 7: Repartition of the three dominant types of forests in the 16 provinces concerned by the project

| Type of forest | Repartition in all the provinces | Hectares saved annually thanks to firewood savings | Hectares saved during 20 years |
|---|---|---|---|
| Tropical dry | 29% | 5.3 | 105.3 |
| Tropical moist deciduous | 70% | 512.4 | 248.9 |
| Mangrove | 1% | 0.2 | 3.3 |
| Total | **100%** | **17.9** | **357.5** |

[5] http://www.nativeforestry.co.uk/firewood.html

### 4.2.4 Emissions savings from the use of bio-slurry instead of chemical fertilizers

According to the biogas user survey of 2010-2011, 39% of households having a BP use the bio-slurry as a fertilizer, either in its liquid form (60%) or composted (40%). To simplify the analysis, we will suppose that this organic fertilizer is applied on paddy field, which in the delta regions is cultivated under intensive practices with an overuse of fertilizers and pesticides. Using the bio-slurry instead of chemical fertilizers has numerous advantages, not only in terms of GHG emissions but also for the water pollution and the households' revenues. The abatement potential of this activity will be detailed in 4.3.1.

### 4.2.5 Side effect of the development of biogas: increase in livestock number

According to the biogas user survey 2010-2011, 72% of the households having a SBP have increased the size of their livestock, by 2.9 pigs. Such side effect can reverse the benefits of the installation of biogas plants. The initial number of pigs has been derived from the 2000-2010 Vietnamese statistics. The estimated number of pigs without the project in 2019 has also been calculated based on the average growth rate for 2000-2010. With the project, we need to add to the normal growth rate the fact that 32,400 rural families (72% of the 45,000 households with a running SBP) will increase their livestock by 2.9 pigs, so in total 93,960 pigs. **Such increase leads to the emissions of 257 796 t $CO_2$-e during 20 years, compare to the baseline.** We assume that large farms with a new MBP or LBP won't increase the size of their livestock.

## 4.3 Technology development and enhancement of CSA practices

### 4.3.1 Improved agronomic practices and water management on paddy rice

The goal of the LCASP project is to achieve a proportion of 40% of irrigated rice managed under CSA practices, compared to 30% in the baseline (LCASP draft final report, 15th April 2012). Using the bio-slurry to fertilize these fields should also increase the productivity of the paddy.

To estimate the paddy surface in 2013 and in 2019 in the 16 provinces, the average annual variation between 2000 and 2010 has been taken, using the Vietnamese statistics. The results are presented in Table 8.

Table 8: Surface of paddy rice in the 16 provinces of the LCASP project

| Hectares of paddy rice | On wetland soils (deltas) | On LAC soils | Total |
|---|---|---|---|
| **2010** | 1 336 100 | 825 300 | **2 161 400** |
| **2013** | 1 299 991 | 785 677 | **2 085 668** |
| **2019** | 1 244 546 | 751 244 | **1 995 790** |

The surface of paddy rice is decreasing, in profit of maize essentially. Such land use change (LUC) needs also to be taken into account, by indicating that 89 878 ha (2 085 668 – 1 995 790) of paddy are converted into annual crops between 2013 and 2019. Such change leads to the emissions of 15 Mt CO2-e in both cases, with and without the project; the carbon balance is therefore null.

Traditionally, rice fields are continuously flooded, with a non flooded pre-season of less than 180 days. The straw is either exported to feed the animals or burned. Without any precise data, we will suppose that there is an equal repartition between these two residues management.

The paddy rice managed with CSA practices (30% in 2013, as well as in 2019 without the project, and 40% in 2019 with the implementation of the project) will be intermittently flooded, with a non flooded pre-season of more than 180 days, and with the application of liquid bio-slurry (assimilated as farm yard manure in EX-ACT) or composted bio-slurry. Indeed, according to the biogas user survey of 2010-2011, 39% of households having a BP use the bio-slurry as a fertilizer, either in its liquid form (60%) or composted (40%).

In both cases, under traditional and improved practices, high productivity varieties are used such as Khangdan or Vietlai. The Vietlai variety has a short growth duration of only 85 to 90 and 115 to 120 days in the autumn and spring cropping season, respectively, as well as a high yielding potential of 6.5 to 8.0 tons per ha (Proceedings of the JSPS International Seminar 2007). Thus the cultivation period in one year is circa 204 days (87 + 117).

**Switching from the traditional paddy rice management to CSA practices enables to avoid the emission of 9 864 708 Mt CO2-e during 20 years**. But it is also necessary to take into account the replacement of chemicals by the bio-slurry.

As for 2002, the chemical fertilization rate was as follow:

Table 9: Fertilization rate on paddy rice

| | Amount of fertilization, in kg/ha |
|---|---|
| **N** | 108 |
| **P** | 45 |
| **K** | 40 |

*Source: IPNI, 2002*

We will use these 2002 figures to estimate the amount of chemical fertilizers used in 2013, 2019 with the project and 2019 without the project (Table 10)

Table 10: Amount of NPK in the project area, for the three situations (initial, baseline, with project)

| | | INITIAL | | WITHOUT PROJECT | | WITH PROJECT | |
|---|---|---|---|---|---|---|---|
| | Fertilization rate in t/ha | Surface fertilized in | Total amount of | Surface fertilized in | Total amount of | Surface fertilized in | Total amount of |

| | | 2013 (70% of total paddy area) in ha | fertilizers in 2013 in t | 2019 (70% of total paddy area) in ha | fertilizers in 2019 in t | 2019 (60% of total paddy area) in ha | fertilizers in 2019 in t |
|---|---|---|---|---|---|---|---|
| **N** | 0.108 | | 157,677 | | 150,882 | | 129,327 |
| **P** | 0.045 | 1,459,968 | 65,699 | 1,397,053 | 62,867 | 1,197,474 | 53,886 |
| **K** | 0.040 | | 58,399 | | 55,882 | | 47,899 |

The amount of bio-slurry spread on the fields is on average 0.175 kg/$m^2$/year, i.e. 1.75 t/ha/year, either in its liquid form (60%) or composted (40%) (Biogas user survey 2010-2011). The average proportion of nitrogen in the liquid bio-slurry is 1.6%, and 2.0% in the composted slurry (Jan Lam, Felix ter Heegde, 2010 and Muhammad Shahabz, 2011). Therefore, around 31 kg N/ha is applied (weighted average of the liquid and composted slurry), very low compared to the current chemical N application of 108 kg/ha. Moreover, recommendations for Asia is to apply 10 t bio-slurry/ha in irrigated area and 5 t/ha in dry area (Jan Lam, Felix ter Heegde, 2010). Our assumption is rather that about 6 t/ha of bio-slurry is applied, to reach a nitrogen rate of 104 kg/ha.

**The carbon balance of the use of bio-slurry instead of chemical fertilizer is a net saving of 1 173 435 t CO2-e.**

### 4.3.2 Adoption of CSA practices on other annual crops (especially maize)

Within the project, trainings on CSA practices will be organized in the participated provinces, and 10 models for CSA based livestock farms will be develop. Thirty training schools are planned, as well as 380 ha of demonstration plots on CSA (spread between 20 rice fields, 20 livestock farms, 20 aquaculture farms and food/tree crop).

It is very difficult to know how many farmers will really implement CSA practices after the training. To conduct the analysis, we have taken a conservative percentage of 33%. Principal CSA practices are minimum tillage, crop rotation and manure application. Tier 1 coefficients are used to estimate the C sequestration of these practices. We suppose that initially and without the project, no maize surface are managed with CSA techniques. As for the paddy rice, estimation of the maize area in 2013 and in 2019 have been made using the average annual evolution of maize area between 2000 and 2010, using the General Statistics Office of Vietnam database. The surfaces are given in Table 11.

Table 11: Surfaces of maize switching to a more sustainable management

| | **Surface in hectares** | | |
|---|---|---|---|
| **Type of management** | 2013 | 2019 without project | 2019 with project |
| **Traditional maize** | 503 921 | 659 154 | 439 436 |
| **CSA maize** | 0 | 0 | 219 718 |
| **TOTAL maize** | **503 921** | **659 154** | **659 154** |

A part of the additional maize surface between 2013 and 2019 comes from the conversion of paddy to maize (89 878 ha) and the rest is supposed to come from the conversion of forest into maize (65 354 ha). Even if such LUC emits GHG, the balance is null because it occurs in both situations, with and without the project**. But the adoption of CSA practices on 33% of the maize area is a net sink of 10 421 221 t CO2-e for the 20 year-period.**

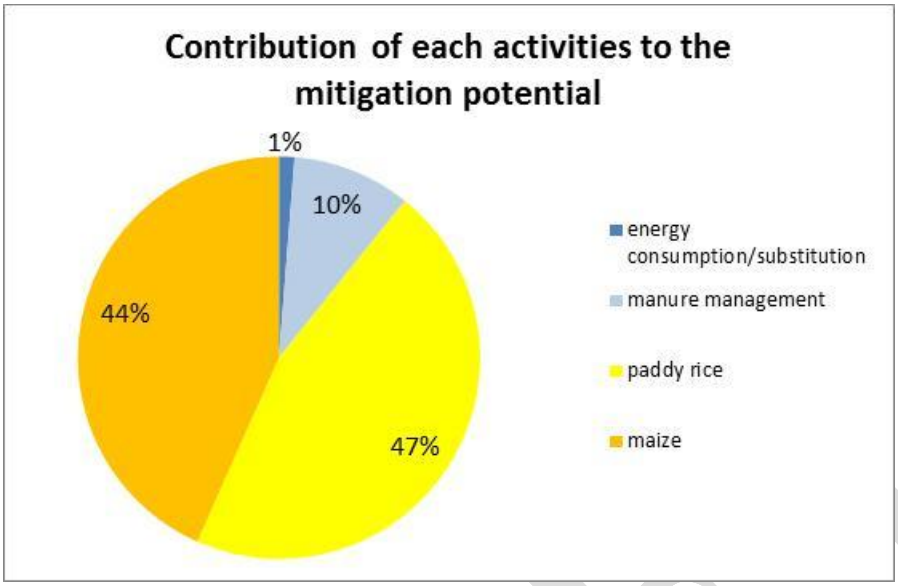
### 4.4 Results: emissions savings thanks to the LCASP project

The results are summarized in Table 12 and Figure 5. Both situations, with and without the project, are a net source of GHG essentially due to the cultivation of paddy rice, the land use changes (conversion of paddy rice and forests into maize ) and livestock.

Table 12: Summary of the GHG abatement per type of activity

| | Emissions without the project in Mt CO2-e | Emissions with the project in Mt CO2-e | Carbon balance in Mt CO2-e | Contribution to the mitigation potential |
|---|---|---|---|---|
| Biogas plants | 56.2 | 54.0 | -2.2 | 9% |
| construction of the BP | - | 0.1 | +0.1 | -1% |
| energy consumption/substitution | 2.0 | 1.7 | -0.3 | 1% |
| manure management | 2.3 | / | - 2.3 | 10% |
| Increased number of pigs | 51.8 | 52.1 | +0.3 | -1% |
| Crops management | 260.5 | 239.1 | - 21.5 | 91% |
| paddy rice, of which | 218.9 | 207.9 | - 11.0 | 47% |
| *agronomic practices* | *196.2* | *186.3* | *- 9.9* | *42%* |
| *fertilization* | *22.8* | *21.6* | *- 1.2* | *5%* |
| maize, of which | 41.6 | 31.2 | - 10.4 | 44% |
| *LUC* | *41.6* | *41.6* | - | *0%* |
| *agronomic practices* | - | *- 10.4* | *- 10.4* | *44%* |
| TOTAL | 316.7 | 293.0 | -23.7 | 100% |

Figure 5: Mitigation potential of the LCASP project by sources




The net benefit of the LCASP project is a sink of about 24 Mt CO2-e during the 20 years of the project. It is equivalent to 1.2 Mt CO2-e/yr and 0.2 t CO2-e/ha/yr.

The great majority of this mitigation potential comes from the adoption of better practices on paddy rice and maize (91%). Although the project is very focused on the biogas component, it is important to highlight the value of the second component, i.e. the diffusion of CSA practices. Nonetheless, some better practices such as the use of bio-slurry instead of urea and chemical fertilizers are linked with the development of biogas plants.

The main benefit of biogas plants is the capture of methane from manure, which would otherwise be released into the atmosphere; mitigation from energy substitution is negligible, because burning the biogas emits almost the same amount of CO2-eq compare to other fossil fuels. However, it avoids the use of limited resources, which will become rarer and rarer as well as more and more expensive. It therefore represents a financial saving for the families.

According to the financial study, the biogas component of the LCASP project should avoid the emissions of 0.9 MtCO2-e during 7 years (or 135 000 tCO2-e/yr). The carbon credits will be sold on the Clean Development Mechanism (CDM) market. Estimation calculated with EX-ACT shows an abatement of 2.5 Mt CO2-e during 20 years (by taking into account the impact of the construction of the BP, the energy substitution and the manure management), so 122,588 t CO2-e/year. The 9% difference between the two figures could be explained by the components taken into account to calculate these emissions. We do not know if the GHG emissions from the construction of the plants are included in the calculations of the financial study, as well as the emissions from manure management. Furthermore, data used by the financial analysis for the quantity of wood, coal and LPG saved do not seem valid. This could explain the difference with the EX-ACT results.

# 5 Sensitivity analysis

As seen in chapter 4.1, the main type of climate is tropical moist, but there are also some regions, especially in the North, with a tropical wet climate. Similarly, the analysis has been conducted on wetland soils, present in the deltas. But for provinces that are not located in the Red River and Mekong delta, the main type of soil is LAC. Which is why it is important to have a look at the variation of the results depending on the climate and the soil. Such analysis is presented in Table 13.

Table 13: Sensitivity analysis

| Case | Climate/soil | Carbon balance in MtCO2-e during 20 years | Difference with the reference case A |
|---|---|---|---|
| A | Tropical moist / wetland soils | - 26.64 | / |
| B | Tropical wet / wetland soils | - 26.64 | 0% |
| C | Tropical moist / LAC soils | - 26.64 | 0% |
| D | Tropical wet / LAC soils | - 26.64 | 0% |

Clearly, the choice of climate or soil has no impact on the results. This is logic for the biogas part of the project (BP construction and energy savings do not depend on the climate and/or the soil). The methane emissions from paddy rice are default value from the IPCC, valid for whatever type of climate and soil. The carbon storage coefficient for improved agronomic practices on annual crops is different only for a cool and warm climate, and for a dry or moist moisture regime. Therefore, the coefficient is the same for a warm moist and a warm wet climate.

The sensitivity analysis could also be done by varying the adoption rate of CSA practices on the maize, as well as the exact number of BP that will be built, since different figures can be found in the LCASP report. Nonetheless, only the percentage of farmers switching to more sustainable practices will have a significant impact on the carbon balance.

# 6 Limits of the present study and further points to analyze in a more detailed work

The present carbon balance appraisal has been done in a limited time, with simplification and basic assumptions. Results should therefore be taken with precautions, and will need to be further analyzed. The points listed below in Table 14 are some examples of the improvements and further details we could include in a more precise analysis of the mitigation potential of the LCASP project.

Table 14: Points to further analyzed

| Biogas | CSA |
|---|---|
| Take into account the emissions from the transport of construction materials | Vary the adoption rate of CSA practices on maize and other annual crops (expect paddy rice). To be more precise, take into account the average size of one farm |
| Take into account the emissions from the transport of the excavated soil | Also include the fertilization on maize, as well as the quantity of organic fertilizers applied |
| We assume that the BP will last 20 years; emissions from the maintenance (e.g. changing the generator every 6 years) have not been included | Problem regarding the definition of "CSA pilot farm". What does it really mean? |

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