Public-Social-Private Partnerships for Ecologically-Sound Agriculture and Resilient Livelihood in Northern Tonle Sap Basin of Cambodia (PEARL)

Annex 3

Economic and Financial Analysis (PART 1)

By

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Currency equivalents

Currency Unit	=	Cambodian Riel (KHR)
US$ 1.00	=	KHR 3,996.5

Abbreviations and acronyms

AEZ	Agroecological zone
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
FOB	Free on board
HH	Household
M$	Million US$
KHR	Cambodian Riel
NPV	Net Present Value
VAT	Value Added Tax
WOP	Without Project (Baseline)
WP	With Project

I. Introduction

1. **Overview**. This Annex reports the results of the financial and economic analysis related to the Project 'Public-Social-Private Partnerships for Ecologically-Sound Agriculture and Resilient Livelihood in Northern Tonle Sap Basin of Cambodia (PEARL). The PEARL Project aims to enhance the climate change resilience of smallholder farmers and local communities in the Northern Tonle Sap Basin (NTSB) by increasing their access to growing premium market segments while using their improved market access to incentivize their transition to climate-resilient practices, mainly through effective public-social-private partnerships.

2. **Structure of the analysis.** The analysis aims at proving the financial and economic viability of the proposed initiatives and the effectiveness of GCF investments, accounted within the overall project costs, which are required to promote project activities reaching smallholders in the target areas. The financial analysis, including crop and household (HH) financial models, is reported in Section II. The economic analysis, which includes a description of the expected Project benefits, is described in Section III. The net benefits derived from the activity level models in the form of incremental benefits with respect to the baseline are aggregated in both financial and economic analyses considering the scale of the project and its targets (total number of households) to assess the overall benefits generated from the proposed project interventions. Such benefits are compared with the project costs (estimated from the project budget) to assess overall investment effectiveness indicators. Crop financial and economic models, as well as a summary of the economic analysis can be found in the attached Excel worksheets.

II. Financial Analysis

3. **Objectives**. The objectives of the financial analysis are: (i) to assess the financial viability of the development interventions promoted under the proposed PEARL Project in Cambodia; (ii) to examine the impact of Project interventions on the incomes of the households (HHs) targeted, therefore determining the incentive for the target group for engaging in the proposed activities; and (iii) to establish the framework for the economic analysis of the Project, which will complement the financial analysis to assess the justification from the perspective of the society rather than the individuals (see Section III).

4. **Data.** Different data sources have been used:

   i) raw primary data about on-farm climate-resilient practices in Cambodia, collected through an *ad-hoc* household survey conducted in 2021. Such data are used to determine the quantities and costs of the inputs used in agriculture management as well the outputs produced. The information refers to both 'conventional' and a range of improved (climate-resilient) farm management practices, as well as input and output prices, at municipality level. Data refer to the 2020-21 production season.

   ii) Secondary data sources have been used to integrate information available and to cross check our findings including previous investment programs in the agriculture sector of Cambodia and data available in the literature.

5. **Methodology, model assumptions and specifications**. The method is based on activity and household models which simulate the implementation of conventional and climate-resilient farming practices for a variety of rainfed and irrigated crops, particularly the project's target crops (i.e., cashew, mango, organic rice and vegetables), grown in the project areas. The

activity models simulate financial budget and estimate financial performance indicators (gross margins, net margins and returns to family labour) that are instrumental for assessing the impact of Project interventions on economic activities of targeted smallholders. Gross margins (cash flow) are computed as a difference between total revenue[1] and total operating (variable) costs. Operating costs include hired external labour but exclude family labour costs. Net margin is derived by subtracting from the gross margins the costs of family labour[2]. Returns to family labour are computed as the ratio between the gross margin and the quantity of family labour involved in the production activity. The economic rationale for PEARL hinges on the increased net margins of agriculture production, primarily resulting from better yields and productivity gained thanks to the adoption of improved climate-resilient farming practices and to switching to high value crops. Indeed, it is assumed that smallholder farmers in the target area – thanks to their advanced knowledge and market access granted through the project – will adopt climate-resilient and improved practices to access the premium market segments for high value crops (e.g., cashew, mango, organic rice, and vegetables), shifting towards climate-resilient and diversified agricultural livelihoods.

6. Crop activity models refer to one hectare of cropland. This will make possible the comparison between different activity models. They simulate annual budgets reporting all the quantities of inputs and outputs, their unit costs and prices. Comparisons of result indicators are made between activities at maturity of the investment. Models should be seen only as indicative, being a representative set of possible smallholder production activities among many others that are eventually combined in complex production systems and investment options. They refer to average socio-economic conditions in the area. An overall conservative approach is adopted in the models not to overestimate potential benefits.

7. All labour is valued in the models using as a proxy the market rural wage (21,779 Riel/person day) derived from the dataset. Since differences exist in the local labour markets, also due to asymmetric information and other sources of market failures in the agriculture job markets, it is not possible to consider them due to absence of reliable data. It must be noted that the wage used here is lower than the minimum wage rate for general worker (31,227 Riel/person-day) as established by the government and effective since 2021[3]. This implies that returns computed through the models presented here are not inflated and are estimated in a realistic manner. Higher labour costs may result in a decrease in the benefits, which is accounted for in the sensitivity analysis. Since the goal of the analysis is to consider all the input costs, labour is valued in the same way, no matter if the labourer is a family member or an external labour. In other words, the analysis looks at labour costs within overall production costs. Most smallholders, however, do not rely on hired labour and use only family labour, without accounting for their labour costs. Therefore, in each crop model, both the gross and net margins are computed (where the net margin is obtained by subtracting the labour costs from the gross margin), to also consider family labour costs. Last, the labour-related indicator *returns to family labour* (ratio between gross margin and total family labour used in farming activities) is established. The returns to family labour indicate how much is earned for each day of work attributed to the crop enterprise, irrespective of who provided the labour. It can be

[1] Total revenue is computed considering all farm production which is valued using the farm-gate market price. No self-consumption is considered, since the analysis is aimed at estimating HHs' incomes in the WOP and WP scenarios and not at indicating how the income is spent. In any case, including food consumption in the computations would not change the analytical results, as there would be no difference between the value of food purchase on the market and the foregone revenue corresponding to the self-consumption.

[2] All costs borne at HH level have been included in the models. Thus, HHs' financial capacity to cover the incremental production costs is already considered in the net margins and corresponding HHs' incomes.

[3] See §104 & 107 of the Labour Law, promulgated by Royal Order No. CS/RKM/0397/01 of 13 March 1997 (amended in 2021); Joint Prakas No. 659 Dated 06 June 2016; Law on Minimum Wage 2018.

compared with the minimum wage to assess the convenience in undertaking the farming activity. In some models, farmers will also be accessing to mechanization services, being able to reduce labour time spent per hectare in land preparation, and expand their cultivated area, or farm their existing land more intensively. It must be noted that there is no difference between the value of food purchase on the market and the foregone revenue corresponding to self-consumption.

8. **Opportunity cost of capital.** The financial interest rate provides the alternative financial returns/opportunity costs to the investor. It is used here to assess the viability and robustness of the investments as compared with market alternatives. The discount rate is estimated at 5.9%, computed as average between: (i) average deposit interest rate paid by commercial or similar Banks in the country; and (ii) lending interest rate (see **Table 1**)[4]. Such rate is used to estimate the financial Net Present Value (NPV) of the production models and the Financial Internal Rate of Returns (FIRR) of the proposed investments.

Table 1. Average interest rate (opportunity cost of capital)

Indicator	Deposit interest rate	Lending interest rate	Average
Rate (%)	1.5%	10.3%	5.9%

Source: International Monetary Fund, International Financial Statistics.

9. **Crop models and financial results.** Crop models include cereals (maize, rice), pulses (soybeans, peanuts), roots and tubers (cassava, sweet potato), vegetables (long bean, water convolvulus, snake gourd, and mung bean, chosen as representative cases) and tree-crops (mango, cashew nuts). Investment costs related to access to finance, technologies, and knowledge needed by the smallholders to adopt climate-resilient and higher-value practices to access the premium market segments for the above listed crops are not considered directly into the crop models since they are already computed within the overall project costs (to avoid double counting). For some crops (aromatic rice, maize, cassava, and soybeans) both conventional and organic/improved management is also simulated. Models' financial results are reported in **Table 2**. Results demonstrate that all crop models are profitable from a farmer perspective illustrating the effectiveness of investments aimed at supporting innovation adoption. Cash flows show that the HHs will have the capacity to cover the necessary operating costs. Detailed information and results are shown in the financial models in the attached Excel file.

[4] In rural areas small farmers mostly avail finance/money from local money lenders where the interest rates are much higher than official figures. Such discrepancy is acknowledged further in the comments to the analysis.

Table 2. Crop models: yields and annual financial results

Crop	Annual net margin ($/ha)
Rice aromatic_conventional	345.5
Rice aromatic_organic	528.1
Rice non aromatic	272.1
Mango	652.1
Cashew nuts	624.8
Long bean	420.2
Water Convolvulus	420.2
Snake Gourd	866.3
Mung bean	315.9
Maize_conventional	670.2
Soybean_conventional	498.4
Cassava_conventional	716.1
Maize_improved	743.1
Soybean_improved	551.7
Cassava_improved	791.9
Sweet potato	127.0
Peanut	57.6

Source: Authors

10. **Representative farm households and incomes.** Crop models presented above are used to assess average yearly income of representative farm households. Since farmers targeted by the Project are represented by smallholder farmers, the present analysis focuses only on this farmer typology, with a lands size of 2 hectares. Indeed, they represent most farmers in Cambodia. Representative farm HHs are built, based on the average land size by crop and AEZ (plain irrigated and hilly rainfed).

11. Two scenarios are considered, 'without project' (WOP, which is the baseline of the analysis) and 'with project' (WP). To make the analysis more realistic, models are representative of the two different agroecological zones which characterize agriculture in the Project areas: irrigated plains and rainfed hilly areas. The WOP scenario refers to ‘conventional’ cropping activities where farmers are not engaged in any improved climate-resilient agronomic practice, yields are below the potential, and the returns to family labour are lower. The WOP models are representative of the current situation which is assumed to remain unchanged during Project implementation. Under the WP scenario, farmers targeted by the project will adopt climate-resilient and higher-value practices to access the premium market segments of high-value crops and diversify crops improving farm financial performance. Labour and overall productivity and farm incomes are expected to increase as effect of the implementation of Project activities. The difference between households’ annual net incomes in the ‘WOP’ versus ‘WP’ scenarios represents the net incremental financial benefits (per HH) of switching from ‘WOP’ to ‘WP’ farming practices through the implementation of the Project.

12. It is noticed that farmers grow a variety of crops, and it is not possible to represent all possible HH cropping patterns. Also, it is not possible to consider all farm sizes and cropping patterns which can also vary by AEZ. Therefore, the land size by household and the land allocation by crop which has been hypothesized here (also considering relevant data and literature) should be considered only as average and representative of the possible combinations of target crops. To be conservative and not overestimate incomes’ increases, rainfed cropland allocation is considered unchanged under both WOP and WP scenarios.

However, it is plausible that several target farmers will have access to irrigation and will be able to expand irrigated crops. The land structure and crop pattern of the representative HH is reported in **Table 3**.

Table 3. Land allocation by crop and AEZ

Representative HH (crop production)	Plain, irrigated		Hilly, rainfed	
	Average cropland area (ha)		Average cropland area (ha)	
Crop	WOP	WP	WOP	WP
Rice aromatic_conventional	0.70	0.35	-	-
Rice aromatic_organic	-	0.25	-	-
Rice non aromatic	0.60	0.30	-	-
Mango	-	0.15	-	0.30
Cashew nuts	-	0.15	-	0.20
Long bean	-	0.15	-	-
Water Convolvulus	-	0.20	-	-
Snake Gourd	-	0.10	-	-
Mung bean	-	0.15	-	-
Maize_conventional	0.30	-	0.60	0.20
Soybean_conventional	-	-	0.50	-
Cassava_conventional	-	-	0.50	-
Maize_improved	-	-	-	0.40
Soybean_improved	-	-	-	0.50
Cassava_improved	-	-	-	0.40
Sweet potato	0.20	0.10	0.20	-
Peanut	0.20	0.10	0.20	-
Total	2.00	2.00	2.00	2.00

Source: Authors

13. Per hectare crop activity models described above have been used to estimate incomes of the beneficiary HHs, by considering activity net margins and HH land structure. HHs' incomes are computed as a sum of the net margins obtained from the crops grown in the HHs. By considering how much land is allocated by each HH to each crop, the HH farm income is computed as weighted average of the net margins of selected crop 'activities' (land allocated to each crop being used as weight). HH incomes both under the WOP and WP scenarios are shown in **Table 4**. Results show that HHs' net incomes would increase because of Project activities, confirming that the proposed production packages are financially attractive for the participants and that the potential gains for beneficiary farmers' from joining Project activities will be attractive, and the feasibility of the proposed activities. Cash flows show that the HHs will have the capacity to cover the necessary operating costs. Farmers may decide to change cropland allocation by growing more of a crop which is found to be more profitable than others. This would result in further income increases. However, since our analysis is conducted in a conservative way, such option is not considered here. Also, it is important to note that farmers may be growing crops under mix/intercropping systems. However, this is assumed not to affect farmland allocation further.

Table 4. Households' incomes from crop production under the WOP and WP scenarios

Representative HH (crop production)	Plain, irrigated		Hilly, rainfed	
	Annual net income ($)		Annual net income ($)	
Crop	WOP	WP	WOP	WP
Rice aromatic_conventional	241.87	120.94	-	-
Rice aromatic_organic	-	132.03	-	-
Rice non aromatic	163.27	81.63	-	-
Mango	-	97.82	-	195.63
Cashew nuts	-	93.73	-	124.97
Long bean	-	63.03	-	-
Water Convolvulus	-	84.04	-	-
Snake Gourd	-	86.63	-	-
Mung bean	-	47.38	-	-
Maize_conventional	201.06	-	402.12	134.04
Soybean_conventional	-	-	249.20	-
Cassava_conventional	-	-	358.06	-
Maize_improved	-	-	-	297.23
Soybean_improved	-	-	-	275.87
Cassava_improved	-	-	-	316.75
Sweet potato	25.40	12.70	25.40	-
Peanut	11.53	5.76	11.53	-
Total	643.13	825.68	1,046.32	1,344.49

Source: Authors

15. Annual incomes are used to compute the average income per person for both WOP and WP scenarios, by AEZ and for various typologies of farm households, to assess the impact of project's activities and investments on HHs' livelihoods. An average size of 4.4 people per household is used in the computations. Results are summarised in **Table 5**. They show that project's interventions are successful in increasing per capita daily incomes helping to fight rural poverty.

Table 5. Per capita daily incomes in rural HHs under the WOP and WP scenarios

Plain, irrigated		**Hilly, rainfed**	
$/day/person			
WOP	WP	WOP	WP
0.40	0.51	0.65	0.83

Source: Authors

III. Economic Analysis

16. **Objectives.** The economic analysis objectives are to: (i) determine the economic viability and overall cost effectiveness of the Project, estimated from the perspective of the society rather than the individuals, through the comparison of aggregated economic benefits with the Project economic costs and the assessment of the economic internal rate of return (EIRR); and (ii) perform sensitivity analysis to measure the robustness of the proposed investments and to measure variations in the overall EIRR due to risk and unforeseen factors, including climatic events. Details of the economic analysis can be found in the attached Excel worksheets.

17. **Methodology and assumptions.** The economic analysis is based on the estimation of the benefits gained from the increased economic performance of the HHs targeted by the Project. The main quantifiable economic benefits from the Project are represented by the net

incremental benefits as computed in the financial analysis, i.e., the difference between the annual net incomes in the WOP and WP scenarios. Such income change are the net incremental benefits of single households. They are then aggregated over the total number of household beneficiaries. The economic analysis is conducted over a 20-year period, including the 8-year Project period. Specifically, the HH models discussed in the financial analysis above are used to link the crop activity models with the number of HH beneficiaries (set as target), estimate the overall flow of benefits, and compute the EIRR.

18. Economic benefits are estimated using economic prices (instead of the financial ones). Financial prices of tradable goods are converted into economic ones using a Standard Conversion factor (SCF) computed as shown in

19. **Table 6**.

Table 6. Computation of the Standard Conversion factor (SCF) for the economic analysis

	M $	Source of data
1) total imports (M)	16,160	WB, 2020
2) total exports (X)	15,793	WB, 2020
3) import taxes (Tm)	2,892.7	WTO, 2022
4) export taxes (Tx)	3,948.31	WTO, 2022
SER	3,931.7	SER=(M+X)/[(M+Tm)+(X-Tx)]*OER
OER	4,066.0	
SCF	0.967	SCF=SER/OER
VAT	0.100	
SCF	0.870	SCF with VAT of 10% also applied to all tradable goods

Source: Authors

20. However, for some key traded goods, specific import/export parity prices at farm gate have been computed with reference to international border prices, applying conversion factors for each category of costs, and eliminating taxes and transfers. Specifically, import parity prices are computed for fertilizers (Urea, Phosphate and Potassium Chloride) which are among key imported items, starting from the international Free On Board (FOB) prices at the nearest port and considering tariffs and taxes, marketing charges and transportation costs. Export parity price is computed for aromatic rice , the most exportable commodity among those targeted by the Project and the present analysis. Details are shown in **Table 7** and **Table 8**.

Table 7. Import parity price for key importable inputs

Commodity	Unit	Urea 1/		Phosphate 1/		Potassium Chloride	
		Financial	Economic	Financial	Economic	Financial	Economic
Price F.O.B, Annual average, 2021	$/mt	483	483	123	123	210	210
Plus:							
- Transport, insurance and freight	$/mt	102	102	102	102	102	102
- Marketing Charges (2.5%)	$/mt	12	12	3	3	5	5
Border C.I.F. price	$/mt	597	597	228	228	318	318
Riel equivalent	Riel/mt	2,428,849	2,348,613	928,495	897,823	1,291,081	1,248,430
- VAT (10%)	Riel/mt	242,885	-	120,704		167,841	
- Marketing Charges (2.5%)	Riel/mt	60,721	58,715	23,212	22,446	32,277	31,211
-Import tariff (17.9%)	Riel/mt	434,764	-	166,201		231,104	
Wholesale border price	Riel/mt	2,732,456	2,407,328	1,072,412	920,268	1,491,199	1,279,641
- Transport to regional market 2/	Riel/mt	74,800	74,800	74,800	74,800	74,800	74,800
- Transport to farmgate 3/	Riel/mt	18,700	18,700	18,700	18,700	18,700	18,700
- Marketing charges (2.5%)	Riel/mt	68,311	60,183	26,810	23,007	37,280	31,991
Farm Gate Import Price	Riel/mt	2,894,267	2,561,011	1,192,723	1,036,775	1,621,979	1,405,132
Farm Gate Import Price	Riel/kg	2,894	2,561	1,193	1,037	1,622	1,405
% of nutrient in product	%	0.46	0.46	0.45	0.45	0.60	0.60
Input subsidy (0%)	Riel/kg	-	-	-		-	
Farm gate market price	Riel/kg	6,292	5,567	2,650	2,304	2,703	2,342
Conversion Factor			0.88		0.87		0.87
1/ Urea: E.Europe; Phosphate: rock.							
2/ 400 km @ $ 0.046 $ per-ton/Km = 187 Riel per-ton/Km							
3/ 100 km @ 187 Riel per-ton/Km							

Source: Authors, based on World Bank Commodities Price Data (The Pink Sheet), retrieved in January 2022

Table 8. Export parity price for exported output

Commodity	Unit	Aromatic rice	
		Financial	Economic
FOB price at port of arrival	$/mt	825	825
Maritime Fret	$/mt	50	50
International Insurance (2% of FOB price)	$/mt	17	17
Exchange rate	Riel/$	4,066.0	3,931.7
CIF price at port of departure	Riel/mt	3,287,361	3,178,764
Export duties (25% of CIF)	Riel	821,840	794,691
Handling (2.5% of CIF)	Riel	82,184	82,184
Storage fee (1% of CIF and duties)	Riel	41,092	39,735
Port fee (50 % of the storage fee and handling fee)	Riel	61,638	60,959
Transportation cost from farm to port	Riel/mt	493,104	493,104
Price at the farm gate	Riel/mt	1,787,503	1,708,091
Price at the farm gate	Riel/Kg	1,788	1,708
Conversion Factor		0.96	

Source: Authors

21. The economic analysis links social discount rates to the long-term growth prospects of the country where the project takes place. Historically, sustained real per capita consumption growth rates ranging from 0% to 5% per year have been most observed. This implies discount rates ranging from 0% to 10% per year[5]. The midpoint of this range is chosen as a benchmark value, as also recommended by the World Bank[6]. This is also in line with the economic growth in Cambodia (GDP has grown on average by 5.06% in the past 5 years (see

[5] See 'Technical Note on Discounting Costs and Benefits in Economic Analysis of World Bank Projects', The World Bank, 2010

[6] See the note prepared by Marianne Fay et al. on Discounting Costs and Benefits in Economic Analysis of World Bank Projects. May 9, 2016. "Where no country-specific growth projections are available, we suggest using 3% as a rough estimate for expected long-term growth rate in developing countries. Given reasonable parameters for the other variables in the standard Ramsey formula linking discount rates to growth rates, this yields a discount rate of 6%. Where there is reason to expect a higher (lower) growth rate, a higher (lower) discount rate should be

22. **Table 9**). Also, an economic cost of labour of 16,344 Riel/day (computed using the SCF reported above, starting from the financial cost of 21,779 Riel/day) is used as a wage shadow rate.

Table 9. Cambodia: GDP growth rate

Year	%
2016	6.933
2017	6.977
2018	7.469
2019	7.054
2020	-3.148
Average	5.06

Source: Authors, based on World Bank national accounts data, and OECD National Accounts data files, retrieved in January 2022

23. **Direct project beneficiaries and flow of benefits**. Project activities will directly target 450,000 households located in the project area, according to the implementation phasing hypothesized in **Table 10**. However, in line with the conservative approach followed in this analysis, it is assumed that not all the target beneficiaries will adopt the proposed climate-resilient management technologies and cropping patterns discussed above. The real adoption rate by year is also shown in **Table 10**. Overall, it is expected that at least 274,500 HHs will adopt the proposed innovations, corresponding to 60% of the target beneficiaries. To compute the flow of direct benefits of the Project, the net incremental benefits of single households are aggregated over the total number of household beneficiaries according to the phasing reported in **Table 10**. In this way, benefits are estimated in a very conservative manner.

Table 10. Number of HHs adopters

Targeted households		Y1	Y2	Y3	Y4	Y5	Y6	TOTAL
Project phasing	%	14%	26%	22%	14%	13%	12%	100%
Hypotethical targets (incremental)	Nr. HH	61,511	114,943	99,644	61,730	56,817	55,354	450,000
Adoption rate	%	25%	40%	55%	65%	80%	95%	60.0%
Adopters (incremental)	Nr. HH	15,378	45,977	54,804	40,124	45,454	52,587	254,324

Source: Authors

24. **Indirect project beneficiaries and benefits.** There will also be large numbers of smallholders who will benefit indirectly from the Project through diffuse knowledge of improved crop production. Consumers would also benefit from more, better quality agriculture products and better prices, with positive effects in terms of improved nutrition and overall food security. In addition to this, all those living in the rural areas where supported households will be located will benefit from strengthened local economies resulting from inflows of income and strengthened local demand. There will also be increased job opportunities for unemployed and underemployed women and men living in rural areas. The expansion of crop production will also promote development of other complementary economic activities of a wide range of inputs and outputs market agents. Thus, the Project activities will indirectly stimulate the whole rural economy benefiting rural population (including the rural poor) through increased demand

chosen. The extreme case of a sustained 6% annual per capita growth over the project lifetime would yield a discount rate of 12%."

for goods and services, additional employment opportunities and possibly reduced rural-urban migration. However, these indirect benefits are not considered in this analysis. In this sense, benefits computed here should be considered an underestimation of total potential benefits of the proposed investments.

25. **Economic Project Costs.** Total project financial costs, invested over 6 years, are derived from the budget reported in the project proposal. They amount at about 42.85M$ including co-finance. Such financial costs have been converted into economic cost using the SCF shown above, obtaining about 37.29M$. Operating costs (e.g., farmer field schools, input starter packs, knowledge and information material and dissemination activities) are hypothesized equal to 5% and are included from Year 7 to 20, as it is assumed that these costs will have to be incurred if the benefits of the Project are to be sustained in the longer run. To avoid double counting of the costs, only the incremental economic costs of the Project are considered (i.e., the costs of activities funded by the project). Costs already included in the estimation of the net incremental benefits of the crop models (e.g., costs directly borne by farmers engaging in the proposed activities or the Project and accounted for in the models) have been excluded as they are incorporated in the aggregation of the HH/activity models.

26. **Project performance indicators (EIRR and NPV)**. The following profitability indicators of the proposed investments are computed as the *Net Present Value* (NPV) and *Economic Internal rate of Return (EIRR)*. The expected EIRR is computed to illustrate the need for GCF funding and overall cost effectiveness of the project from the social perspective. The overall EIRR of the Project is estimated at 45.8% (base case) which is well above the opportunity cost of capital (see **Table 1**) confirming the economic justification of the Project from the social standpoint. Since the adoption rate is assumed to be only 60% of target farmers, in case of higher adoption rates, the EIRR will increase further. In addition to this, the analysis only considered the economic benefits at farm-gate. The indirect benefits to upstream and downstream actors in the value chain from increased trade volumes, quality and value adding opportunities beyond those mentioned above, have not been considered due to estimation difficulties. The economic NPV is estimated at about 84M$ over the 20-year period of the analysis, with the benefit stream based on the quantified benefits as specified above. The discount rate adopted in the economic analysis is 5%, as discussed above.

27. **Sensitivity Analysis**. To test the robustness of the above results, a sensitivity analysis has been carried out to incorporate the forecasted impact of climate change on agriculture productivity under the WOP scenario and to measure variations due to unforeseen factors and relevant risks. The climate change impacts modelled into the analysis is aligned with the overall climate change rationale for the Project. Indeed, the extreme complexities of downscaling global climate models and the uncertainty of projecting climate variables in monsoonal geographies are acknowledged here. The sensitivity analysis takes all this into account by simulating the following scenarios: 10 and 20% cost over-run, benefits increment, benefits decrease, and 1 and 2 years of benefits delays. Results are presented in **Table 11**. It is found that the proposed project is robust from the economic standpoint, since the project is profitable under all simulated changes. The table also shows that the minimum number of adopters required to have a positive NPV (break-even point) amounts to 157,988 HHs, corresponding to an adoption rate of about 31%.

Table 11: Results of the economic and sensitivity analysis

Performance indicators	Base case	Cost increments		Benefits increments		Benefits decrease		Benefits delay	
		+10%	+20%	+10%	+20%	-10%	-20%	1 year	2 year
EIRR	**45.8%**	40.0%	35.4%	52.4%	59.3%	39.5%	33.4%	31.1%	38.1%
NPV @ 5% (000 $)	**84,083**	44,834	41,966	55,338	62,975	40,063	32,426	39,311	45,567

Break-even point (adoption rate)	
Minimum number of beneficiaries to have a positive NPV (HH)	157,988
Corresponding adoption rate (%)	31.3%

Source: Authors

28. **Risk analysis.** The bulk of risk to be considered in the sensitivity analysis relates to: a) delays from some of the institutions charged with the responsibilities of implementing and/or overseeing the implementation of some of the Project activities; b) farmers reluctant to fully engage in the Project and adopt the farming practices disseminated; c) worsening of the macroeconomic scenario; d) increased climatic risk affecting temperatures and water availability consequent to climatic changes; and d) discontinuation of practices once the project ends. **Table 12** reports the impact of each of the key risk components on Project economic performance indicators. The probability of occurrence is supposed to affect the entity of cost/benefit increases/decreases reported above, i.e., a low probability translates into a 10% decrease in benefits (or a 1-year delay in benefits), while a medium probability is supposed to determine 20% benefits decrease (or a 2-years benefits delay). It is important to notice that these impacts should be considered as indicative and are based on the information available in the literature and in the feasibility study.

Table 12: Risk analysis

Risk description	Probability of occurrence	Proxy to compare with sensitivity analysis results	EIRR (%)	NPV (000 $)
INSTITUTIONAL: Limited Institutional capacity	Low	Benefits delay 1 year due to implementation risk	31.1%	39,311
ECONOMIC: Worsening of the macroeconomic scenario	Medium	Increase in costs due to the enhnaced input costs	35.4%	41,966
SOCIAL: Farmers reluctant to fully adopt the farming practices disseminated	Low	Decrease in benefits due to the lower adoption rate	39.5%	40,063
CLIMATIC: increased risk affecting temperatures and water availability	Medium	Increase in benefits due to the worsening of the WOP scenario	59.3%	62,975
POLITICAL: Discontinuation of practices once the project ends	Low	Decrease in benefits due to the suspension of climate-resilience practices and benefits capitalization	39.5%	40,063

Source: Authors

IV. Conclusions.

29. Overall, our analysis has shown that a wide adoption of climate-resilient and improved farm management would have important financial and economic benefits in the form of better on-farm returns which can support smallholder farmers becoming more market-oriented, with expected positive results in terms of overall HH’s livelihood and reduced poverty. The financial analysis demonstrates that, due to the implementation of project activities, household beneficiaries would increase their financial annual net incomes by 28%. The aggregate Financial Internal Rate of Return (FIRR) is 38.7%, well above the opportunity cost of capital, showing the financial effectiveness of the planned activities and providing a strong justification for the GCF grant request. Such rate is expected to increase e.g., up to 50% in case of benefits

increments by 20% (plausible given the conservative analytical assumptions) confirming the convenience of the proposed investments even with higher opportunity cost of capital[7]. The financial analysis also shows that the aggregate NPV is 73.1M$, confirming the attractiveness of the proposed investments.

30. The economic analysis has confirmed the robustness of the investment, from the society's standpoint: overall EIRR of 45.8% even in the case that only 60% of the targeted beneficiaries would adopt the proposed climate-resilient agricultural practices and cropping patterns. The results are strongly positive as shown in the sensitivity and risk analyses for adverse situations as cost over-runs, reduction of prices for their agricultural products, and even reduction in the rate of adoption; as well as for all the risk categories, included the climatic risk. These indicators - while monitoring performance during the implementation of the Project - can provide valuable information for adjusting the strategy and interventions to improve the Project impact.

31. The analysis has been conducted based on the available information and data and to the best of available knowledge. The validity of the analytical assumptions may limit our findings. All assumptions and calculations are transparently shown in the attached Excel file which is made accessible to the reader.

[7] See the attached Excel file for further details.

ANNEX: INTEGRATED ECONOMIC AND ENVIRONMENTAL ASSESSMENT WITH SOCIAL ACCOUNTING MATRIX

Authors Enrico Mazzoli and Giacomo Branca

1. Introduction

Project evaluation is normally carried out by using analytical methods whose examination spectrum is restricted within the economic domain. Project desirability and aptness is often assessed by looking exclusively at income generation potentials or financial indicators. Nevertheless, the increasing evidence on climate change and loss of biodiversity has contributed to raise awareness on the need to integrate economic decision-making with environmental accounting. Nowadays, to help policy makers monitor interactions between the environment and the economy, national statics are more closely integrating environmental and economic accounts (United Nations, 1993). Improvements in strategic planning and decision-making processes are achieved by making allowance for the accounting of gas emissions and depletion of natural resources, linked to economic growth. Meanwhile, the use of such statistics in the evaluation process, allow gathering full evidence of economic choices – and their consequences – accounting for the private and social costs of the use of natural resources and the degradation of the environment.

In our study, we present an integrated analytical framework where the economic and environmental accounts of Cambodia are combined. This framework represent a hybrid between the 'national Accounting matrix including environmental accounts' (NAMEA) developed by De Hann, Bosch and Keuning (1994) and the 'social accounting matrix' (SAM) developed by Pyatt and Round (1985). In the technical literature, this hybrid takes various names, among which: a) 'social accounting matrix including environmental accounts' (SAMEA), and b) 'environmentally extended social accounting matrix' (ESAM). Both names indicates an accounting framework where national economic accounts (expressed in monetary units) and environmental accounts (expressed in physical units) are integrated. In our study, we will use the name 'SAMEA' to describe our tool.

The objective of this study is three-fold. Primarily, we want to use the SAMEA to analyse the economic and environmental impacts associated to the implementation of a newly development programme financed by the Green Climate Fund (GCF) and implemented by the Food and Agriculture Organization (FAO) in Cambodia. Secondly, we want to sustain the work of international agencies and financial institutions that are responsible for promoting sustainable development, by demonstrating that the application of integrated quantitative tools supporting decision-making process is possible also in those countries where information is limited. Finally, environmental statistics on Cambodia are limited and there are no published work on the use of SAMEA in the country; hence, we aim at fulfilling this two-pronged gap through this study.

Following this introductory section, the rest of the report is organised as follows. Section 2 describes the methodological framework of our SAMEA, starting from a comprehensive description of the SAM structure. Data sources and the estimation procedure is described in section 3. The section 4 analyses the SAMEA multiplier in Cambodia. Section 5 provides the results of the quantitative analyses and simulations. Finally, section 6 gives some concluding remarks on this study.

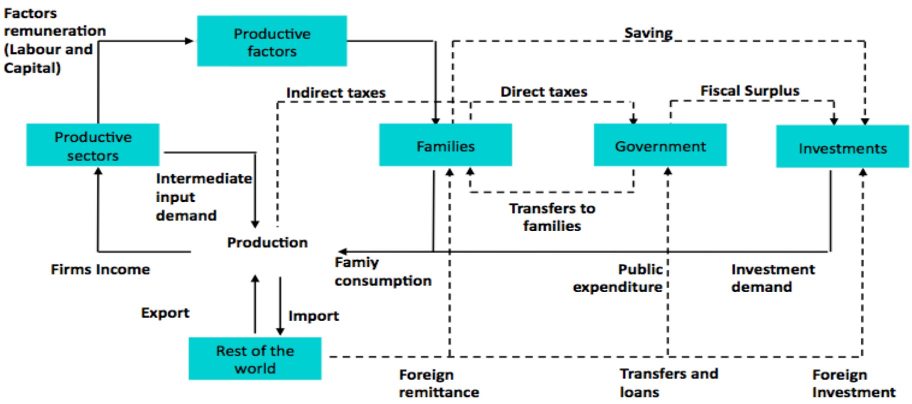
2. Methodology

2.1. The Social Accounting Matrix

The SAM is considered an extension of the traditional Input-Output[8] (I/O) model proposed by Leontief (1966), which records in monetary terms the exchange flows occurred within an economic system, during a specific period of time (usually a year). The matrix allows investigating and analysing the relations occurring within and between economic sectors through the different phases of the production, distribution, utilization and income accumulation process.

As shown in Figure 1, any economic system can be described by the circular income circuit where economic agents, productive sectors and institutions are connected one another through real transactions. Families' inflows for instance relates to remuneration of capital and work sold in the market, government assistance in the form of social transfers, and foreign remittances from the Rest of the World (RoW)[9]. Conversely, families decide to allocate their wealth on both consumption and savings following their preferences, once taxes - both direct and indirect - are paid. In such a comprehensive framework, each actors' outflow becomes someone else's inflow and, considering that all transactions between people and institutions are monitored and quantified, the system does not present leakages.

Figure 1: The circular income circuit



Source: Ferrarese and Mazzoli (2018)

Therefore, the SAM consists of a set of interrelated subsystems that, on the one hand, provides the analytical framework of the studied economy tracking monetary flows occurring between sectors. On the other hand, it measures the structural changes within the economy (i.e. injections and multiplying effects in the system) resulting from a policy change or a project intervention.

The information is compiled in a double entry table (i.e. the matrix), describing the structure of the economic system through disaggregation in key blocks (i.e. actors, productive factors and activities), assumed as origin and destination of transaction flows. Each key block is disaggregated further into accounts headed to the institutional sectors (e.g. type of households, specific commodities, productive sectors) depending on data availability. Typically, the economic system is separated into the following blocks:

i. Primary production factors (Labour and Capital);
ii. Households (eventually disaggregated by income or income source);
iii. Government (Public Administration);
iv. Production sectors and Commodities (Agriculture, Industry, Services and their disaggregation);

[8] The Input - Output accounts provide detailed industry and commodity accounts and show the supply and demand flows in a specific economy.

[9] The Rest of the World can be defined as another Country/State, Region or geographical area depending whether the scale of the analysis is National, Regional or Local-wide respectively.

v. Savings and Investment (Public and Private gross fixed investments);
vi. Rest of the World.

In a typical SAM structure, columns represent the outflows of the different economic agents that is, the expenditure of any aggregate with respect to the others, while rows represent the inflows, namely the income formation. Since total incomes equal total expenditures[10], including savings and capital formation, the SAM is a square and balanced[11] matrix. A simplified scheme of the SAM is presented in Figure 2.

Figure 2: A simplified SAM scheme

	Productive Factors	**Household**	**Government**	**Production sectors and Commodities**	**Savings and investment**	**Rest of the World**	**Total inflows**
Productive Factors		Domestic Employment	Government Employment	Value-added		Payments from abroad	Total factor income
Household	Labour incomes and profits	Inter-household transfers	Social transfers			Foreign remittances	Total household income
Government	Taxes on labour and profits	Direct taxes		Indirect taxes	Taxes from capital account	Foreign grants and loans	Total Government income
Production sectors and Commodities	Domestic supply	Private consumption	Recurrent spending	I/O Matrix (intermediate demand)	Investment and stock	Export payments	Total demand and activity income
Saving and Investment		Private savings	Fiscal surplus			Current account balance	Total savings
Rest of the World	Factors payments abroad	Household transfer	Government transfers	Imports payment			Total imports
Total outflows	Total factors spending	Total Household expenditure	Total Government Expenditure	Total Gross output	Total investment spending	Total Export	

Source: Ferrarese and Mazzoli (2018)

An interesting evaluation in the context of developing countries relates to the simulation of structural changes of the economy in response to policy changes. Some of the questions this analysis could respond are for example: What would happen to the economy if technical change in agricultural production were brought in? How would the economy change after a shift in imports? What would be the trickle-down effect due to the establishment of a new production activity?

Such interventions cannot be simply studied as the effects of an increase in households' disposable income since changes in the economy have potential important effects on the structure of the SAM in terms of coefficients and multipliers. For instance, long lasting impulses in the Agricultural sector would generate an increase in rural household income that would trigger a rise in goods and services demand. Thereafter, a likely increase in goods and services supply would generate a structural change within the local economy.

2.2.1. Structure and accounts of the Social Accounting Matrix

[10] Surplus or deficit in the balance of trade are compensated within the "rest of the world" account.

[11] A square matrix contains an equal number of rows and columns while a Matrix is balanced when the sum (total value) of each row is equal to the sum (total value) of each column for each of sectors included.

Typically, a Social Accounting Matrix has six basic groups of accounts:

- Activities and/or Commodities;
- (Production) Factors;
- (Private) Institutions - Households and Corporations/Enterprises;
- Government (public institution);
- (Combined) Capital accounts;
- Accounts for the Rest of the World.

Activities and Commodities (goods and services)

The activities accounts represent all the agents producing Commodities (goods and services). SAM flows can be valued at production costs in the accounts of Activities and at market prices (including indirect taxes on raw materials and transaction costs or margins) in the Commodities accounts. Sum of values of Activities is the domestic production (at production prices). Adding imports, net taxes on products and margins gives the total supply of commodities (at purchaser's prices). Supplied commodities are sold domestically or exported.

Activity accounts detail the cost structures of production and payments to factors. Activity expenditures report the use of commodities as intermediate inputs, and the use of factors of production (labour, capital, etc., quantified by salaries, wages, mixed income, rents, interest, etc.). The sum of factor remuneration plus taxes and subsidies on production is the value added by activities. Activity incomes report the value of the commodities produced and marketed, in basic prices.

Expenditures on commodity markets include the domestic production by activities, imports (Rest of the World accounts) and payment of taxes - including VAT - or receipt of subsidies on products, domestic and imported, and government accounts. Commodity supply is valued at purchaser prices.

In a SAM, trade flows (national and international) might be associated with transaction costs (trade and transport). For each product (goods or services), the SAM records costs associated with costs of transportation and marketing of imports and exports. Trade and transport margins for domestic production sold on the domestic market represent the cost of moving the product from producers to consumers.

Factors

The production factors consist essentially in capital and labour, although other factors may be added, such as land or other natural resources. The disaggregation of production factors is very important depending on the objective of the analysis. The breakdown of labour (by occupation groups, education level or social characteristics, etc.) allows a more detailed analysis of employment issues, and the capital factor can also be disaggregated in accordance with their use i.e. agricultural/non-agricultural capital.

The production factors receive income from productive activities and the Rest of the World. These incomes (wages, rent, etc.) are distributed (as expenditures by factor accounts) to owners of factors of production, namely: (i) domestic institutional sectors: households (as labour income and distributed profits), incorporated business enterprises (as non-distributed profits), and Government (as taxes and payment for owned resources); and (ii) the Rest of the World.

Households

Households receive income from Factors sold on domestic or foreign markets (as owners of labour, capital and land or natural resources) and transfers from Government, Enterprises, the Rest of the World and (potentially) other households. Household incomes from Enterprises are basically distributed profits (and sometimes direct transfers), while from Government are mostly direct transfers. Payments from abroad come usually for labour services (capital services are most often paid to enterprises).

Households' revenues are employed to consume commodities (goods and services, marketed and valued at purchaser prices including margins and taxes), payment of direct taxes (income taxes, etc.) and transfers to other institutions (domestic and foreign, including other groups of households when they are broken down).

Incorporated Business Enterprises

Incorporated Business Enterprises are institutions that own activities and receive payments related to asset ownership (i.e., capital and land or natural resources) and transfers from other institutions. Those revenues are employed to pay direct taxes (corporation tax), transfers to other institutions or converted in savings. Generally, corporations do not consume any goods (they represent the institutional part of the productive sector).

Government and Public Sector

Government accounts refer to the Public Administration institutional sector. Its share as “productive activity” (public corporations) and marketed goods and services resulting from its activities are recorded in the respective accounts of Activities and Commodities. General government as institutional sector can be represented by a single account which collects incomes for transferring owned production factors, transfers and taxes. However, it is typically subdivided into an account for the sector itself and in other accounts representing different types of taxes, allowing a better analysis of fiscal policies and a better interpretation of economic flows.

Saving-Investment (capital combined accounts)

This account records in its row the savings generated by all domestic institutions as well as transfers (positive or negative) of capital from foreign institutions (accounts of Rest of the World, balance on the capital account). The column records the investment expenditure in goods and services to produce new capital, the Gross Fixed Capital Formation (GFCF) and changes in inventories in the accounts of Commodities, including investment in the economy. Gross investment itself can be separated from the changes in inventories.

Rest of the World

The Rest of the World (ROW) account’s incomes, in the row, are the value of imports of goods and services (Commodities), payments to the factors of production from outside and transfers from the domestic institutions to institutional sectors elsewhere. Foreign sector accounts expenditures are the purchase of goods and services (exports), payments to national factors of production used abroad and transfers recorded from other economies. The balance reflects the current account (surplus or deficit) with the Rest of the World.

2.2. Social accounting matrix including environmental accounts

In order to perform a deeper analysis of the project impact on the environment, the established SAM framework has to be expanded to include separate accounts for natural resources and pollutants. The inclusion of environmental accounts is done by adding rows and columns to the SAM, to quantify pollution and the consequences of containment actions. Flows can be accounted for in physical or monetary terms. In this study, the entries in the environmental accounts are in physical unit only. These additional accounts link the economic system to the environmental dimension and enable an integrated reading of economic and environmental phenomena. Thus, the SAMEA allows to determine the environmental consequence of economic investments and consumption by linking productive sectors to environmental accounts.

The SAMEA estimated in this work has a structure based on the criteria formulated by the System of Integrated Environmental and Economic Accounts (United Nations et al 2014) and the System of National Accounts (SNA 2008) (United Nations et al. 2009). However, since environmental accounts are not expressed in a monetary unit as the SAM accounts, they could not be fully reconciled with the SNA structure, hence were treated separately as satellite accounts.

The environment section of the SAMEA contains two flow matrices expressed in physical units. By rows, the first matrix shows the flows of natural resources that the production system uses as inputs (e.g. water resource abstractions) or the natural resources reabsorbed in the system (e.g. waste that is collected and processed). By columns, the second flow matrix shows, the flow reabsorbed by nature (e.g. water discharge) after its use for production and consumption purposes, as well as the related greenhouse gas (GHG) gas emissions. A simplified scheme of the SAMEA is presented in Table 16.

The typical accounts considered to populate the environmental dimension refer to: a) the main pollutants responsible for the GHG emissions; b) Waste produced or absorbed in the economic system because of the production activity; c) the natural resources depleted/discovered; and d) the environmental themes.

GHG emission account

By columns, this account presents the origin of pollutants by consumers and producers and trans-boundary pollution from the rest of the world. The three main sources of emissions are production, consumption and international imports. The export of emissions appears in the intersection between GHG emission and ROW. By rows, it shows the absorption of pollutants into the economic processes. The list of pollutants embedded in the account is presented in Table 13.

Table 13: List of pollutants tracked in the environmental accounts

Aggregated Substance	
Carbon dioxide (CO_2)	Methane (CH_4)
Nitrous Oxide (N_2O)	F-gases
Disaggregated substances	
Air pollutants	
Ammonia (NH_3)	Black Carbon (BC)
Carbon monoxide (CO)	Nitrous oxides (NO and NO_2), expressed as NO_2 (NO_x)
Non-methane volatile organic compound (NMVOC)	Organic Carbon (OC)
Particulate Matter 10 (PM10)	Particulate Matter 2.5 (PM2.5)
Sulphur dioxide (SO_2)	
Toxic pollutants	
Divalent Mercury (Hg_D)	Gaseous elemental mercury (Hg_G)
Particulate associated Mercury (Hg_P)	Total Mercury (Hg)

Source: Own elaboration

Waste account

Waste produced or absorbed as a result of the production and consumption activities is presented in a separate account. By column, the account shows the emission of waste while by row it shows the absorption of waste into the economic processes (e.g. recycling).

Natural resources account

Loss and regeneration of natural resources, such as biomass, minerals, fossil, water and forest, are presented in a dedicated account. The columns shows the addition to stocks – linked to discovery of regeneration of natural capital – while the rows present the use of resources by economic activities.

Environmental themes account

This account refers to environmental indicators at both global and national scale. At global level, the indicators include global warming effect generated by emission of GHGs and ozone depletion. This indicates how Cambodia contributes to the global warming issue. The Kyoto protocol established that six gases contribute to global warming, namely: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydro fluorocarbon (HFCs) and per fluorocarbons (PFCs). Due to lack of data on some of the emissions, our calculation includes the following greenhouse gases: CO2, CH4, and N2O. Similarly, we could not determine the effects on the ozone layer due to the lack of data on those gases responsible for its depletion (ie. SF6, HFCs, PFCs).

The contribution of each gas to the global warming issue is based on the global-warming potential (GWP) – over 100 years – that each gas withhold. The estimated gas emission is multiplied by the corresponding a weighting factor (i.e. GWP) and it is expressed in CO2 equivalent. The GWP factors used in this analysis are those established by the sixth assessment report (AR6) of the Intergovernmental Panel on Climate Change (IPCC 2021) and are summarized in Table 14.

Table 14: IPCC sixth assessment report global warming potential

Greenhouse gas	GWP over 100 years
CO2	1
CH4 (fossil origin)	29.8
CH4 (non-fossil origin)	27.2
N2O	273

Source: IPCC 2021

At national scale, the account includes the effects related to acidification, other air pollution, waste production and loss of natural resource, whose effects are only relevant within the country. The acidification effect is determined by aggregating the emission of three gases, namely: nitrogen oxides (NOx), sulphur dioxide (SO2) and ammonia (NH3).

The indicator related to 'Other pollutant' aggregates all those gases not directly responsible for the greenhouse gas effect or acidification. Therefore, the following gases are considered: black carbon (BC), carbon monoxide (CO), non-methane volatile organic compound (NMVOC), organic Carbon (OC), particulate matter 10 (PM10), particulate matter 2.5 (PM2.5) and mercury-related pollutants (Hg).

The waste indicators provides an estimate on the total amount of polluting waste generated by all economic activities during the referenced period. Finally, the indicator on the loss of natural capital reports depletion on biomass, mineral ores, fossil, water and forest resources. In Table 15 , we provided a summary on the substances contributing to various environmental themes.

Table 15: Summary table on substance contribution to environmental themes

Environmental themes	Substances

Greenhouse effect	CO_2, CH_4, N_2O
Acidification	NO_x, SO_2, NH_3
Other air pollution	BC, CO, NMVOC, OC, PM10, PM2.5, Hg
Waste	Waste
Loss of natural resources	Biomass, minerals, fossil, water, forest

Source: Own elaboration

Table 16: A simplified scheme of the SAMEA

	Productive Factors	**Household**	**Government**	**Production sectors and Commodities**	**Savings and investment**	**Rest of the word (ROW)**	**GHG emissions**	**Waste**	**Natural resources**	**Environmental themes**
Productive Factors									Discovery and renewal of resources	
Household							Emission from consumption	Waste from consumption		
Government										
Production sectors and Commodities				SAM			Emission from production	Waste from production		
Saving and Investment										
Rest of the World (ROW)							Transboundary emission from ROW			
GHG emissions		Absorption from consumption		Absorption from production		Transboundary emission to ROW				Accumulation of pollutants
Waste				Waste absorbed						
Natural resources	Extraction and depletion						Emission from land use change			Net reduction / depletion
Environmental themes	GHG inventory				Environmental indicators					

Source: Own elaboration

2.3. Beyond the SAM - Analysis of effects in the long run

Currently, the model we developed here does not include a long-term analysis on how the PEARL project may sustain a change in production and productivity thanks to the adoption of sustainable agriculture practices. Similarly, due to the lack of a proper counterfactual, our study does not allow to analyse how changes in agronomic practices promoted under PEARL may perform – both economically and environmentally – in comparison to an alternative investment.

Nonetheless, in this section we present the methodological framework that may simulate long-term impacts on both demand and supply as well as structural changes brought by the project. To achieve that, we could redefine our simulation framework on a variant of the I-O linear model, which takes into account not only Leontiev's direct multiplier, but also those resulting from changes in the coefficients of the matrix. In fact, the traditional analysis of SAM is based on so-called open Leontief model described by the equation:

$$\Delta X = (I - A)^{-1} \Delta Y$$

where ΔY is a vector of exogenous shocks to the *n* sectors, institutions and factors of production represented in the array, ΔX is the vector of induced changes in the levels of activity of those sectors and A is the SAM matrix of coefficients.

Coefficients along the columns of the matrix express both input purchases by production sectors (final and intermediate products, products and factors of production) and purchases of final goods by households in different income brackets and the other institutions. Along the rows, the coefficients measure the captivation of income of each sector and institution from other sectors and institutions. In the case of the productive inputs such as labour and capital, those represent payments received by the sectors. For this reason, the simulation of the effects of a project capable of increasing climate mitigation effect and altering agriculture productivity can be through a variation of the coefficient matrix, according to the equation:

$$\Delta X = (I - A^*)^{-1} [(\Delta A) X + \Delta Y]$$

where A e A* are the SAM matrixes with and without the change, and ΔY is the vector of exogenous changes in income or capital expenditures.

3. Data sources and estimation of parameters

In the present analysis, the basic structure of the SAMEA for Cambodia was built upon several sources. The Cambodia Input-Output table of 2018, sourced from the OECD statistical database, provided the primary base for the estimation. Later, the I/O table was updated with most recent available data to ensure reliability of estimated impacts. In order to update the SAM values to most recent data using the World Bank Country Economy Data, Cambodia National Statistics Office and Asian Development Banks Statistics (ADB). Additional data were also collected from the main international organisation databases the international labour organization (ILO) and the International Monetary Fund (IMF). In particular, we use economic data from the World Bank database on GDP and value added by economic sector and from the ADB for a disaggregation of the economic sector. Historical data from households' consumption and population collected by the national institute of statistics (NIS) were also used.

Therefore, the construction of the SAM used the following data and information sources:

- An Input-Output framework, with the Supply and Use tables or the Symmetrical table, fully reconciled with the main macroeconomic accounts based on the OECD I/O table (OECD 2022)
- National Accounts (aggregated and sorted by institutional unit). This integrated accounts, show, by institutional sectors, the flow of payments to and from institutions as double-entry accounts, from production to the primary and secondary distribution of income. Key sources used to populate the accounts were the ADB key indicator database (ADB 2021)
- Data on consumption patterns and household expenditure, as well as households' income. Household budget surveys or similar surveys (levels of poverty surveys, time use surveys, etc.) are a basic and key source and sometimes as important as the Input-Output framework (specially to analyse socio-economic issues related to inequality of income distribution effects on welfare, etc.) (NIS 2015, NIS 2018).
- Environmental data and statistics were obtained from various sources depending on the data need. In particular:
    - Emission data on GHG emissions were extracted from the EDGAR v6.0 dataset of Joint Research Centre (JRC) (Crippa et al. 2021a) and from World Resource Institute (WRI) through the historical emission tool (WRI, CAIT, 2022)
    - Emission data related to food-system were sourced from the EDGAR-FOOD v6.0 dataset of JRC (Crippa et al. 2021b)
    - Data on CH4 and N2O emissions were extracted by the VERIFY 2020 project dataset of JRC (Crippa et al. 2020) and from the Environmental Protection Agency (EPA) of the United States (EPA 2019)
    - Data related to material flow extraction and import were extracted from the Global Material Flows Database of the United Nations environment Programme (UNEP) and the International Resource Panel (IRP). In detail data extraction concerned for biomass (i.e. crops, crop residues, grazed biomass and fodder crops, wood, wild catch) metal ores (i.e. ferrous and non-ferrous), non-metallic minerals (i.e. construction dominant and industrial or agricultural dominant) and fossil fuel (i.e. coal, oil shares and tar sands, natural gas, petroleum) (UNEP-IRP 2018)
    - Forestry data were obtained through the Global Forest Watch database (2022) or sourced from Harris et al. (2021), Hansen et al (2013) and FAO (2022a)
    - Data on water use was sourced from the AQUASTAT dataset of FAO (2022b)
    - Energy data were sourced from the International Energy Agency (IEA) database (IEA 2021)
    - Waste data were extracted from Kaza et al. (2018).

Currently, the Cambodia SAMEA for 2020 includes 94 accounts divided into:

- 10 agriculture activity sectors, including 8 sub-sectors by type of commodity produced (i.e. grains-legumes, rice, fruits, mangoes, tubers, cassava, sugarcane, other agriculture)
- 22 industry sectors
- 19 service sectors
- 1 Value added sector grouping productive factors (i.e. labour and capital)
- 11 institutional accounts represented by 10 categories of representative households differentiated as rural vs urban households and further disaggregated by per capita consumption quintiles, and the Government account
- 17 polluting substances
- 5 natural resources
- 5 environmental themes
- 4 additional accounts concerning taxes, capital formation (i.e. savings and investments), rest of the world and totals.

4. Sectors economic linkages and multiplier analysis in Cambodia’s economy

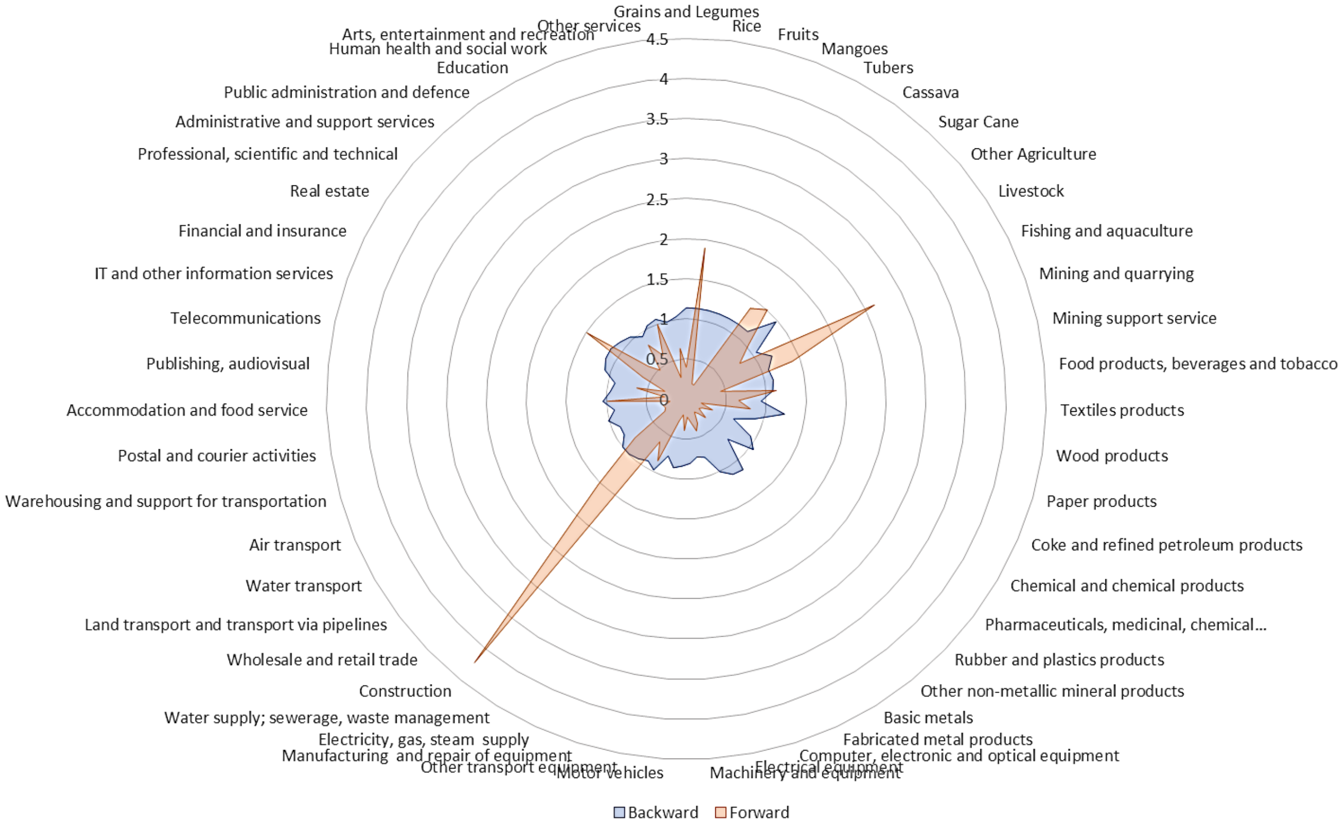
Once the characteristics of Cambodia's economy are identified, we carry out a sectoral static analysis based on the multipliers' analysis of the economy (see Figure 1). The latter describes how an exogenous expenditure (change) in one sector will be transmitted to the interconnected sectors on the economic system. In other words, this step of the analysis reveals which are the most reactive sectors able to either absorb or transmit further economic stimulus, thus generating higher multiplying effects in the economy.

The analysis also makes a distinction between the forward and backward multipliers. Forward multipliers measure the importance of a sector as a supplier of goods and services to upstream sectors. Sectors possessing low forward multipliers indicate that they sell their output mostly to final demand. Vice versa, sectors possessing high forward multipliers provide intermediate inputs to upstream industries.

Backward multipliers reveal the importance of a sector as a centre of demand for the rest of the economy to downstream sectors. Low backward multipliers indicate that a sector dependence on other sectors' inputs is comparatively very low (i.e. inputs are sourced mainly from imports). On the contrary, sectors with high backward multipliers shows a stronger bond to local industries downstream, which are responsible for the supply of intermediate goods.

Figure 1 indicates forward (in orange) and backward (in blue) multipliers with respect to all sectors included in the Cambodia SAMEA. The results show that the highest forward multipliers are in construction and in fishing and aquaculture that are relevant input suppliers to all other industries and sectors upstream. Agricultural sectors tend to show lower forward multipliers, which means they mostly sell their produce to final demand rather than agro-processing industries, exception made for rice, sugarcane and cassava. The backward multipliers in Cambodia present a more homogenous set of results.

Figure 1: Backward and forward multipliers for Cambodia



Source: Own elaboration

5. Quantitative results and simulations

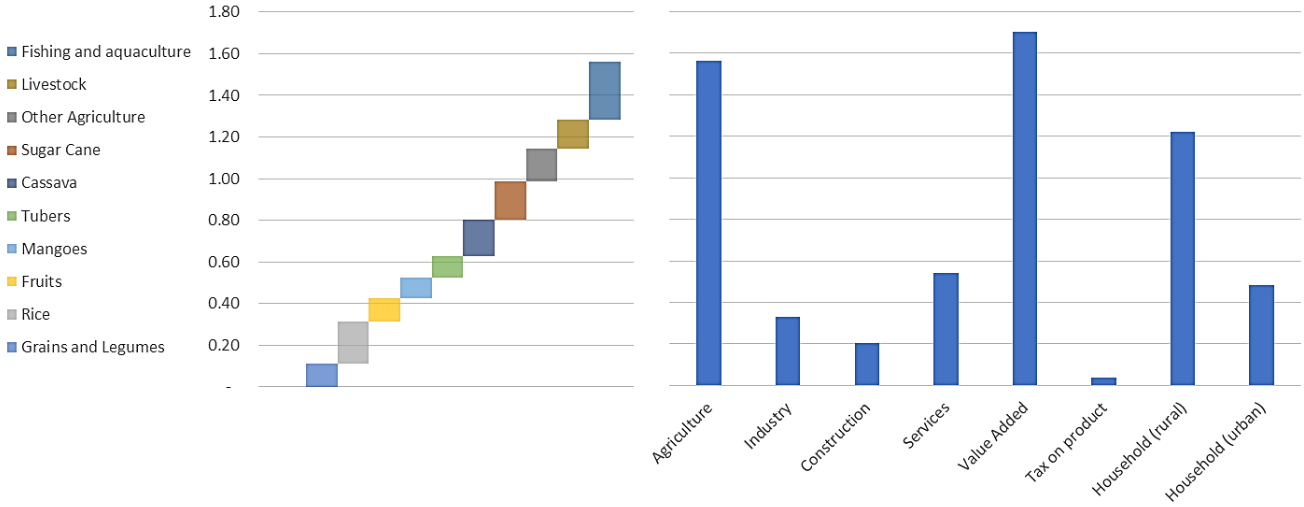
This section shows the effect of investments and policy reforms through two sets of simulations. The first focuses on the expected impact that a generic investment in the agricultural sector would have on the upstream and downstream markets and sectors, as subdivided in the SAM. The second simulation analyses the economic impact of implementing the set of interventions foreseen in the PEARL GCF project.

5.1. Analysis of the economic and environmental effects of agriculture expenditures

The first simulation aims at measuring how independent incremental expenditure in specific agricultural sectors may affect other sectors. In particular, this analysis allows to compare sector performance - in terms of multiplier effect – and to define the leverage capacity each sector expresses as a driver for growth in other sectors.

Figure 2 shows how a yearly expenditure in the indicated agricultural sectors (see vertical axis) of one US dollar will contribute to activate downstream-upstream related economic sectors. One primary evidence is that rural households and services are more sensitive to the initial spending in agriculture. These results can be justified observing that these two sectors are more closely connected to the agricultural sector; hence, they are those with the highest capacity to absorb the initial shock. In addition, it is worth noticing that the multiplier for the value added is equal to 1.74, meaning that for each dollar spent, an additional 0.74 dollar is generated in economy.

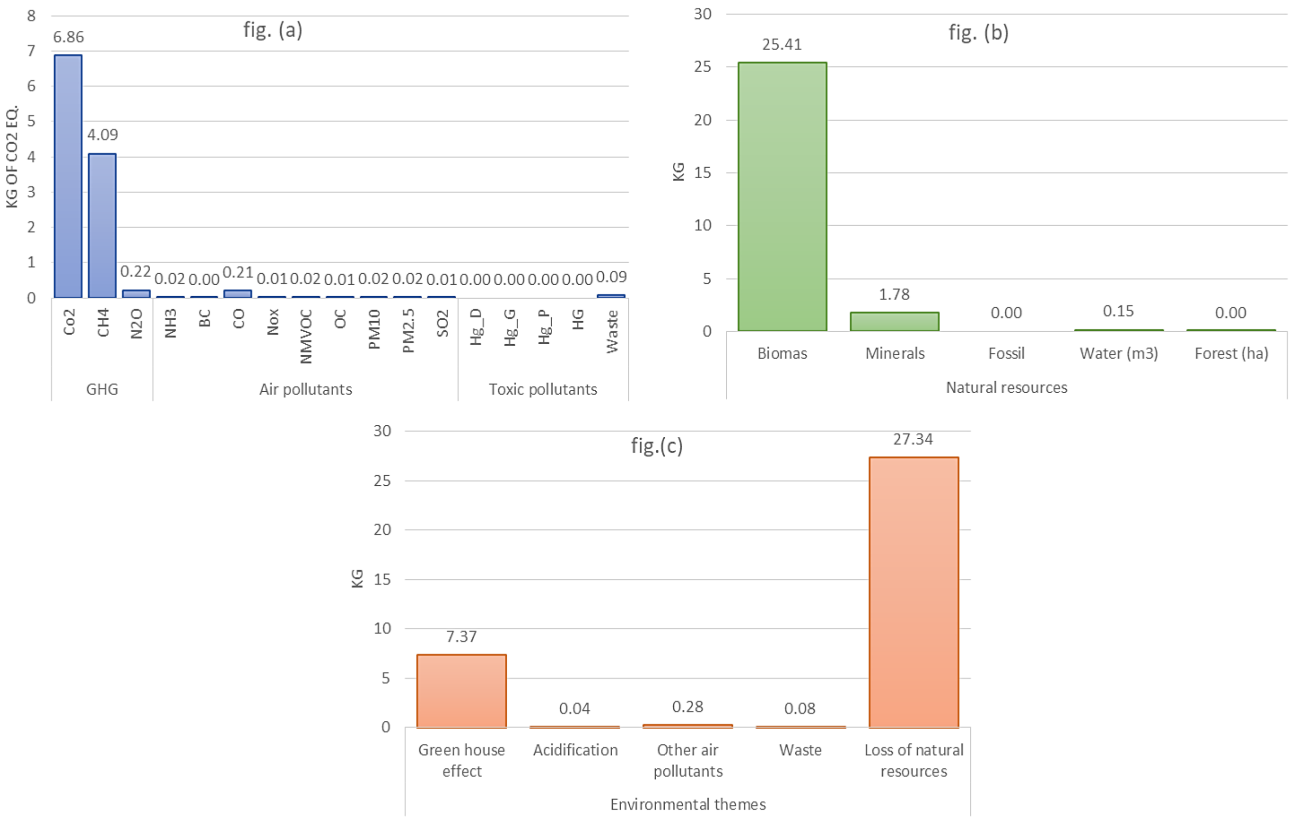
Figure 2: Economic impact of spending in agriculture (dollars)



Source: Own elaboration

Another interesting simulation concerns the impact and the pressure on natural resources due to the increased economic activity, within and beyond agricultural sectors. As shown in the Figure 3, a surge in spending contributes to an increase in emissions, particularly for carbon dioxide and methane (figure 3a). At the same time, an increase in spending does also increase pressure on natural resources, as shown in figure 3b. Finally, effects on the environment can be grouped based on their contribution to some of the environmental issues monitored through the environmental sub-matrices (figure 3c and Table 15).

Figure 3: Emissions (fig. a), natural resources usage (fig. b) and environmental themes (fig. c) linked to increase in spending



Source: Own elaboration

5.2. Short-term economic and environmental effects of the GCF Investment in Cambodia

5.2.1. PEARL GCF investment in Cambodia

To assess the macroeconomic effects of the strategic plan and policies on migration as detailed in the project documentation of the Public-Social-Private Partnerships for Ecologically-Sound Agriculture and Resilient Livelihood in Northern Tonle Sap Basin (PEARL). We considered the budget allocated and the sector of interest for each budget line. Based on the latter, we simulated the contribution to economic growth (direct and indirect impacts) that a proper implementation of the GCF project would bring about.

Currently, the PEARL project will be implemented over 6 years, with a total budget of USD 42.8 million. The project budget is allocated to four components as summarized in Table 17.

Table 17: Project cost by component (USD)

Project components	Allocated budget (USD)
Component 1: Farmers' capacities are enhanced to manage climate impacts and related risks	3396,366
Component 2: Adaptive capacity of smallholder farmers and other local value chain actors, particularly women farmers and value chain actors, is increased through climate-resilient, high-value, and sustainable agriculture	33,543,160

Component 3: Enabling conditions for climate-resilient agriculture are ensured through a coherent and robust policy, legal, and institutional framework.	2,804,235
Monitoring and Evaluation	1,065,980
Project Management Cost	2,040,490
Total budget	**42,850,231**

Source: Own elaboration of PEARL budget data

This budget constitutes the economic stimulus that is required in the short run to bring returns in terms of productivity increase and sectors development. In order to simulate the economic and environmental impact of the project, the detailed PEARL budget has been re-classified according to the standards used to compile the SAMEA.

The harmonization procedure allows us to construct an investment matrix, which considers the expenditures occurring over the six years of implementation. It is worth noticing that the amount of resources included in the investment matrix will not match the total budget of the project. This is because the analysis accounts only for those financial resources that are invested on the national territory. Therefore, those resources spent on the international markets (e.g. international consultancy) are not included in the investment package presented in Table 18.

Table 18: PEARL GCF investment matrix - Annual expenditure (USD)

SAMEA Sectors	Y1	Y2	Y3	Y4	Y5	Y6
Grains and Legumes	56,356	35,261	33,186	32,722	32,523	32,545
Rice	93,926	58,769	55,311	54,537	54,205	54,242
Fruits	37,571	23,508	22,124	21,815	21,682	21,697
Mangoes	93,926	58,769	55,311	54,537	54,205	54,242
Tubers	37,571	23,508	22,124	21,815	21,682	21,697
Other Agriculture	56,356	35,261	33,186	32,722	32,523	32,545
Accommodation and food service activities	418,090	743,674	564,007	500,918	506,766	457,978
Air transport	41,223	36,408	27,621	33,479	28,250	29,921
Chemical and chemical products	18,215	72,861	72,861	72,861	72,861	72,861
Coke and refined petroleum products	317,129	395,756	395,756	395,756	346,614	317,129
Computer, electronic and optical equipment	68,962	145,624	4,587	4,587	4,587	4,587
Electricity, gas, steam and air conditioning supply	28,502	43,245	43,245	43,245	43,245	43,245
IT and other information services	216,961	181,333	109,095	109,095	109,095	109,095
Land transport and transport via pipelines	52,868	33,089	30,755	29,895	29,649	24,735
Machinery and equipment	2,146,515	3,577,525	1,100,777	-	-	-
Manufacturing; repair and installation of machinery and equipment	6,552	26,209	26,209	26,209	26,209	26,209
Motor vehicles, trailers and semi-trailers	50,780	6,552	6,552	6,552	6,552	6,552
Professional, scientific and technical activities	3,381,350	2,115,688	1,991,187	1,963,324	1,951,382	1,952,709
Public administration and defence; compulsory social security	1,194,209	1,276,914	1,250,378	1,241,532	1,241,532	1,241,532
Publishing, audio visual and broadcasting activities	124,853	147,163	137,728	137,728	137,728	137,728
Telecommunications	77,185	126,327	125,344	126,327	126,327	126,327
Wholesale and retail trade; repair of motor vehicles	18,870	2,457	2,457	2,457	2,457	2,457
Administrative and support services	360,373	419,344	419,344	419,344	419,344	419,344
Water supply; sewerage, waste management and remediation activities	119,578	242,433	242,433	242,433	242,433	242,433
Postal and courier activities	6,552	26,209	26,209	26,209	26,209	26,209
Other service activities	39,313	39,313	39,313	39,313	39,313	39,313
Total	**9,063,790**	**9,893,200**	**6,837,100**	**5,639,410**	**5,577,373**	**5,497,331**

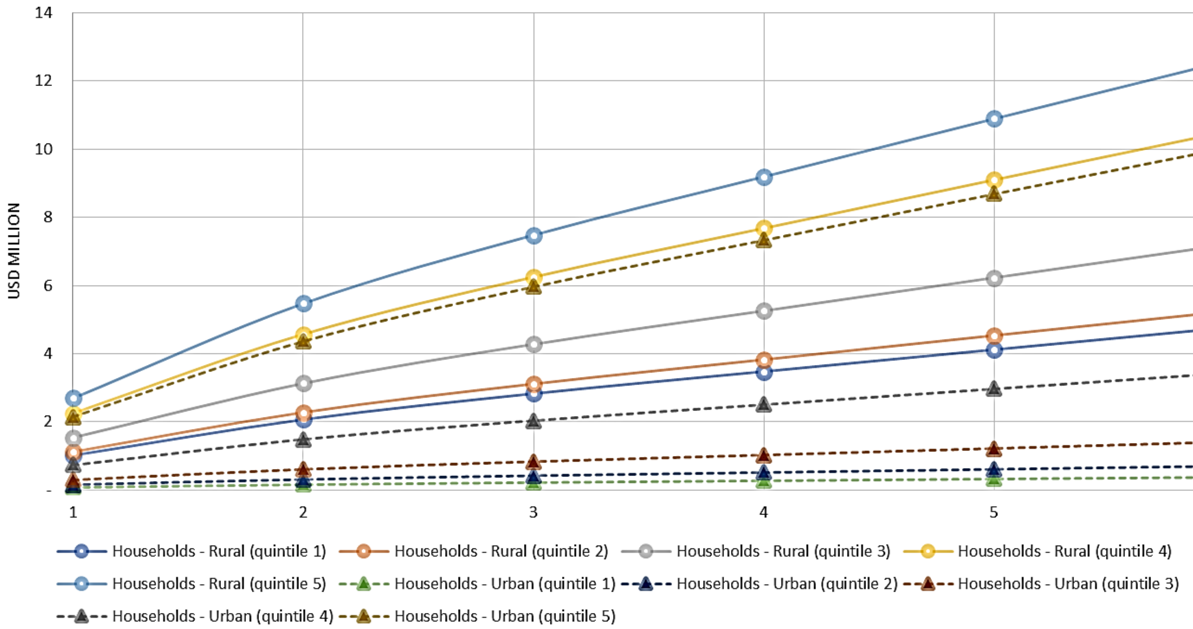
Source: Own elaboration

5.2.2. Analysis of the economic impact of the PEARL GCF investment

Economic impacts in the short run are related to the implementation of the project and of the investment plan. Over the expected enactment period, the budgetary expenditure will have an impact on national GDP, household and government incomes, per capita consumption and value added.[12] Given the structure of the SAMEA, we can also analyse economic impact on household income distribution, differentiated by wealth levels (i.e. per capita consumption quintiles) and living settings (i.e. rural or urban).

According to our simulation, the implementation of PEARL is expect to bring about a positive economic impact on the whole population. As shown in Figure 4, the project implementation would benefit primarily rural households and predominately the richest quintiles (fourth and fifth). However, the present value of the income generated by the project appear to be more evenly distributed across rural households, rather than within the urban household cluster (Figure 5).[13] The present value of the cumulative government income– and composed by direct and indirect taxes on products, profits and capital – is of USD 4.14 million.

Figure 4: Cumulative economic impact on households' income (mil. USD)

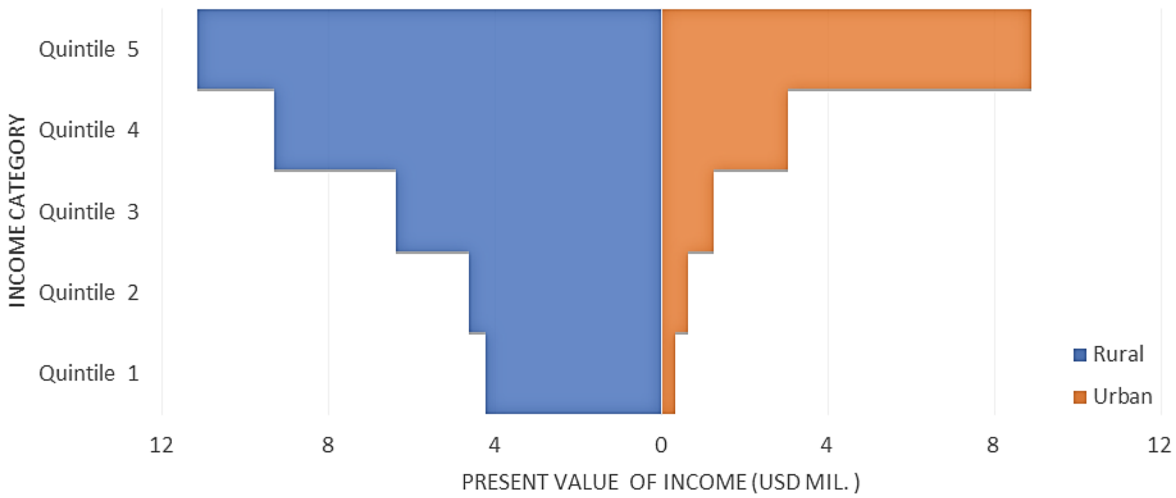


Source: Own elaboration

[12] The national GDP is measured as the sum of all value-added in the economy. Increase in the value-added denotes increase in value of production and distribution of goods and services through the introduction of production factors (capital, labour, land and livestock) from intermediate goods (raw materials and non-primary inputs). This can be calculated as the difference between the value of the goods produced and the value of the intermediate inputs used for production or, in an equivalent manner, as the value distributed to productive factors (labour and capital) and government through indirect taxes.

[13] The present value of the income is calculated as the sum of yearly incremental incomes generated during the project implementation phase, discounted at five per cert.

Figure 5: Present value of incremental income by household quintiles (USD Mil.)



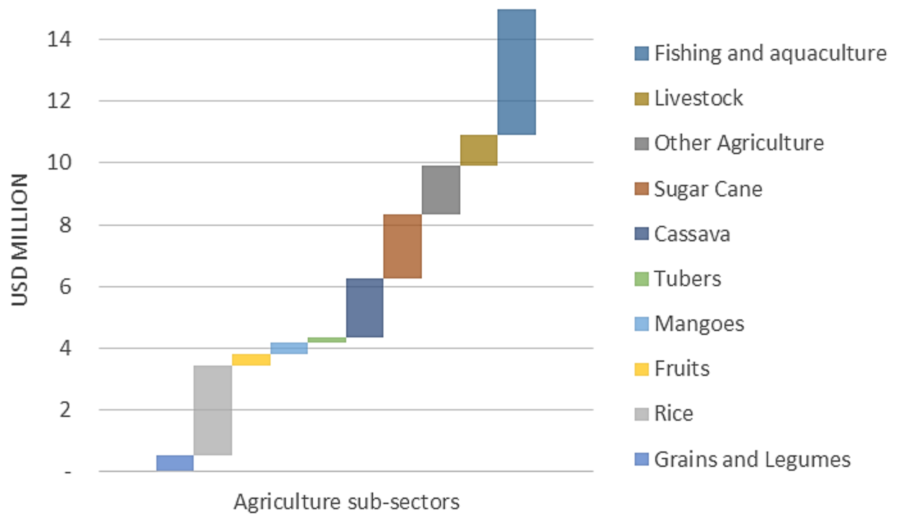
Source: Own elaboration

The project is also expected to play a part to national GDP growth. In particular, over the six years of implementation, our simulation determined a cumulative impact on the Cambodia economy equivalent to USD 53 million, with a multiplier effect of 1.38 per USD dollar spent. Out of the total value created, USD 50.74 million are linked to the direct and indirect sectoral stimulus generated by the project. An additional USD 2.20 million are associated with incremental tax revenues for the government. [14] Therefore, the project will contribute to an annual GDP growth of 0.04 per cent and a cumulative contribution of 0.23 per cent, over the implementation period.[15]

Concerning the effects on agriculture, the greatest impacts are registered in those sub-sectors more strongly integrated in the economy, namely: fishing & aquaculture, rice, cassava and sugar cane (Figure 6). As indicated in section 4, the capacity of a sector to absorb and further replicate an economic stimulus relates directly to the forward and backward multipliers involved. As a whole, the PEARL investment will trigger a chain reaction within and beyond the agricultural sub-sectors directly supported by the initial spending. In fact, while the project budget will sustain production of organic rice, cashew, mango and vegetables – as well as investing in other service and industry sectors - the indirect economic stimulus will be strongly perceived in highly interconnected agriculture sub-sectors (e.g. fishing, cassava or sugar cane). On the national economy scale, the greatest stimulus are produced in the service sector (Figure 7). A consolidated summary on the economic impact is provided in Table 19.

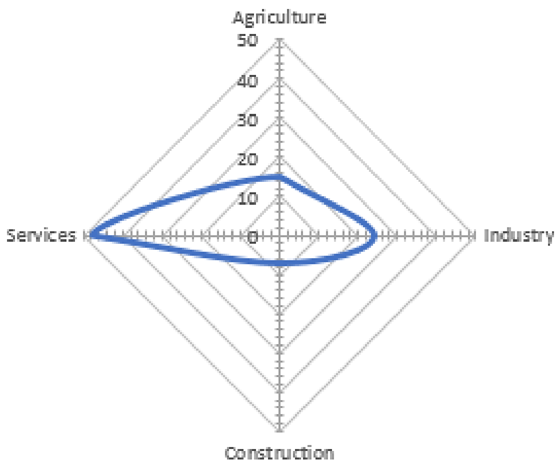
[14] Value are expressed in present values equivalences, discounted at five per cent.
[15] According to the latest available statistics from World Bank, Cambodia GDP in 2020 was equivalent to USD 25.29 billion.

Figure 6: Cumulative economic impact on agriculture sub-sectors (present value - USD million)



Source: Own elaboration

Figure 7: Cumulative impact on main economic sectors (present value - USD million)



Source: Own elaboration

Table 19: Summary table on PEARL direct and indirect economic impact (USD million)

	Present values		Notes	Present values
Activity sectors		**Institutional sectors**		
Agriculture	14.98	Rural households	quintile 1	4.30
Grains and Legumes	0.54		quintile 2	4.73
Rice	2.88		quintile 3	6.49
Fruits	0.40		quintile 4	9.48
Mangoes	0.36		quintile 5	11.35
Tubers	0.15	Urban households	quintile 1	0.35
Cassava	1.94		quintile 2	0.64
Sugar Cane	2.06		quintile 3	1.27
Other Agriculture	1.59		quintile 4	3.09
Livestock	0.98		quintile 5	9.05
Fishing and aquaculture	4.08	Government		4.14

Industry	23.88	**GDP**		
Construction	7.00	Value added		50.74
Services	46.64	Taxes on products		2.20
		Multiplier effect	USD generated / USD spent	1.38

Source: Own elaboration

5.2.3. Analysis of the environmental impact of the PEARL GCF investment

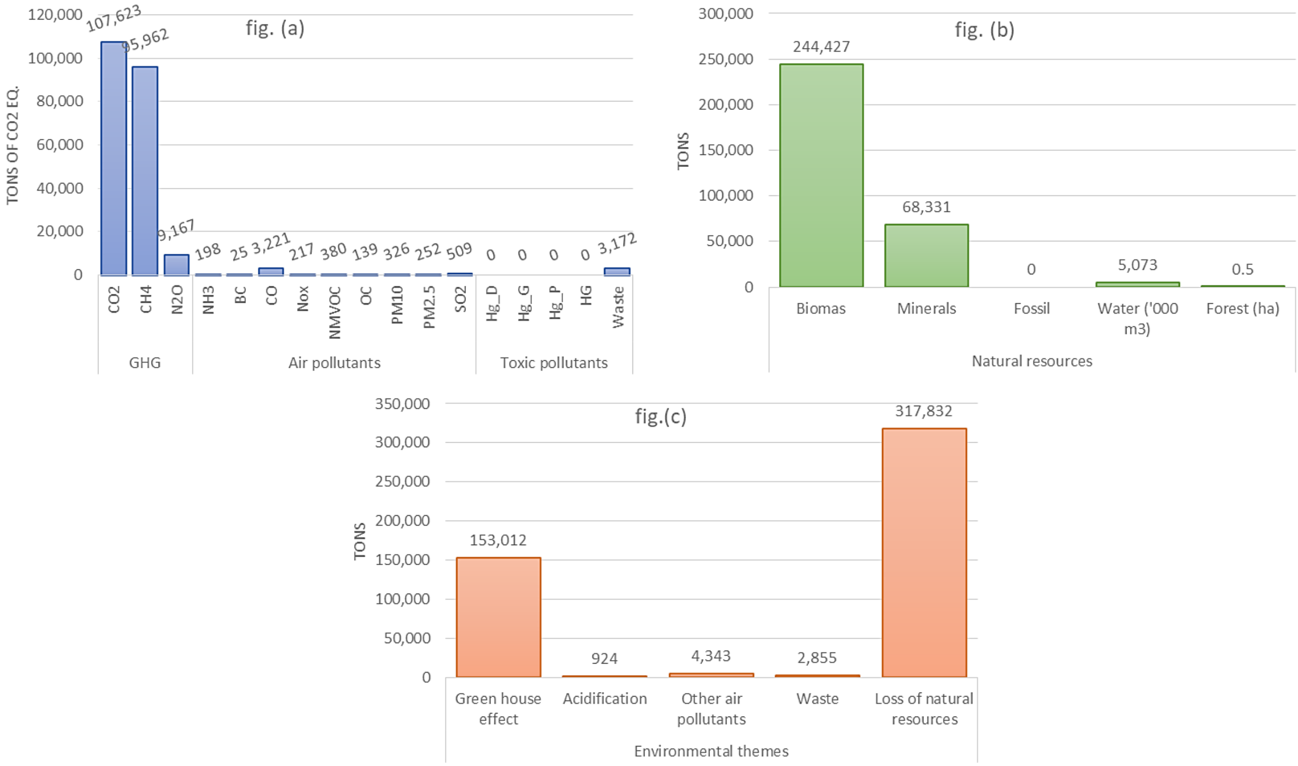
As mentioned, one of the main advantage of using SAMEA in project evaluation relates to the capacity to link the economic domain to the environmental dimension. Therefore, the SAMEA allows for an integrated analysis of the environmental consequences that originates with the project implementation.

In our analysis, we monitored the emission of main substances (see Table 13) and consequences on relevant environmental themes (see Table 15) linked to PEARL investment. Here, it is worth noticing that our analysis determines the environmental footprint of PEARL only, and excludes any comparative analyses on how the PEARL environmental performance may compare to alternative investments suited to achieve similar development objectives. Nevertheless, had we performed such analysis, we would have expected PEARL to showcase a greater environmental performance as compared to a project adopting conventional agriculture practices. We posit our statement on the fact that PEARL promotes climate-resilient and sustainable agriculture rather than conventional agricultural. The technical and scientific literature provides numerous evidence on the extent to which climate-smart agriculture performs better than conventional agriculture in reducing GHG emissions (Ariani et al. 2018; Kakraliya et al. 2021; McNunn et al. 2020; Panchasara et al. 2021; Susilawati et al. 2018; Win et al 2021).

In Figure 8 we present the cumulative emissions of substances (fig. a), the depletion of natural resources (fig. b) as well as the net effect on environmental themes (fig.c) linked to the direct and indirect growth induced by PEARL. The cumulative GHG emissions – obtained by combining the values of CO2, CH4 and N2O – amounts to 212,752 tons of CO2 eq., corresponding to the 0.3% of the total GHG emissions produced by Cambodia in 2018 (WRI, CAIT 2022).[16] Similarly, the analysis on the usage of natural resources indicate a major use of biomass and minerals. Finally, the analysis of the net effect of the project on the environmental themes shows a loss of natural resources and a net increase in greenhouse gas effect. The latter registered a net cumulative emission of 153,012 tons of CO2 equivalents.

[16] Total greenhouse gas emissions including land-use change and forestry, measured in tonnes of carbon dioxide-equivalents (1990 – 2018). In 2018, Cambodia emitted 69.15 million of CO2 equivalents.

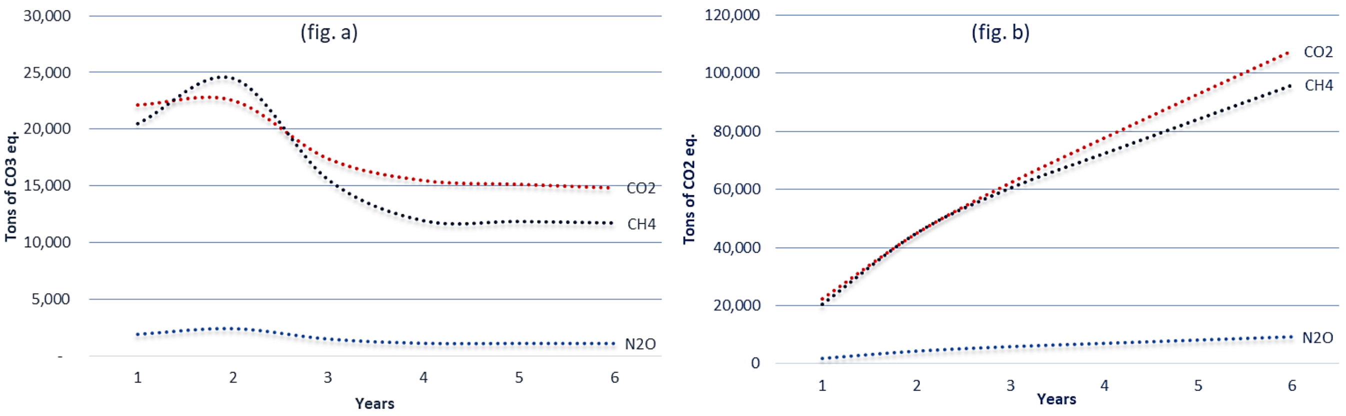
Figure 8: Cumulative emissions (fig. a), natural resources usage (fig. b) and net effects on environmental themes (fig. c)



Source: Own elaboration

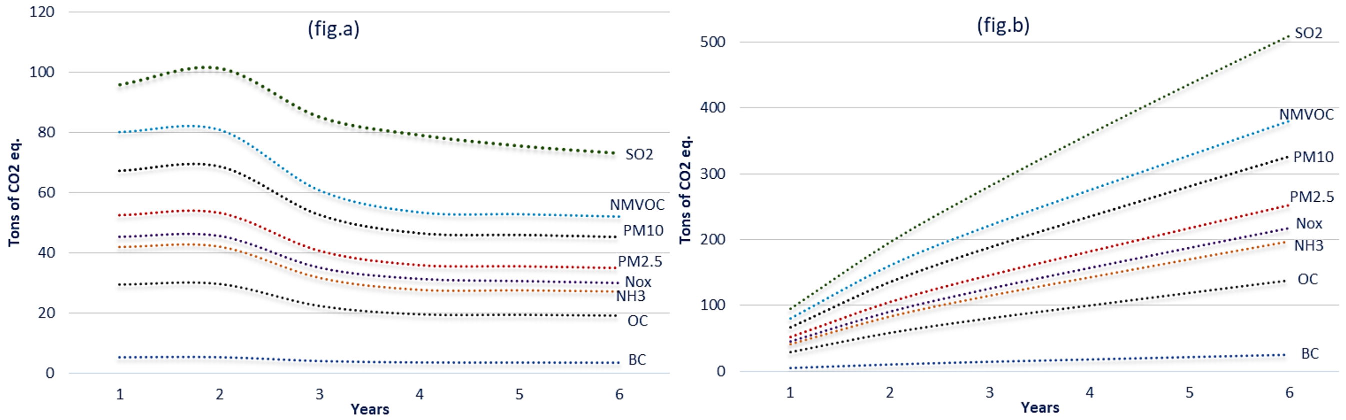
Finally, we can analyse annual emission trends of key substances grouped by polluting effect, that being either global warming or air pollution. As shown in **Error! Reference source not found.**, the emission of three main gases responsible for global warming is expected to prevail at the beginning of the project implementation period. It is important to notice that this result is proportional to the budget expenditure pattern and the implementation schedule assumed for PEARL. Similarly, we can also notice that CO2 and CH4 gases account for the larger share of total emissions, with CO2 prevailing over CH4 by the end of the implementation period. Concerning air-polluting gases (Figure 10), higher emissions are registered for SO2, NMVOC and PM10, while lower emissions are noted for BC and OC.

Figure 9: Annual (fig. a) and cumulative (fig. b) emission trends of global-warming gases



Source: Own elaboration

Figure 10: Annual (fig. a) and cumulative (fig. b) emission trends of air-polluting gases



Source: Own elaboration

6. Conclusions

The contribution of this paper is the construction of SAMEA of Cambodia for the year 2020. We showed that comprehensive analytical tools, as this one, can be effectively used to display the existing connections between the economic and the environmental domains. Furthermore, we demonstrated that such type of analysis can be used to better advice project preparation and inform stakeholders on the expected economic and environmental consequences that development projects may bring about. To that regard, we related the impacts of production and consumption activities on environmental variables - like GHG emission, and change in natural resources – while also analysing income distribution on a national scale.

Further to that, our analysis has demonstrated that sectoral economic growth and GHG emissions may not be linked by a one-way linear transmission. Instead, these are often determined by the strength of both backward and forward linkages between sectors. Ultimately, the multiplier coefficients tying the economic and environmental sectors are responsible for the direct-indirect changes on both the economy and the environment.

Finally, a limitation of our study is that we could not provide an analysis of the project impact on the longer run, where technological changes in the production function can take place. Similarly, we could not provide a comparative analysis of the project results vís-a-vís an alternative investment scenario. Yet, we have established the methodological framework that may help defining how the adoption of technological changes and production practices – such as those promoted under PEARL – could improve the environmental footprint of the project and reduce GHG emission. The shift in the production function paradigm can alter production coefficients and redefine backward and forward linkages between economic sectors and environmental indicator.

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