Annex 22: Climate Adaptive Irrigation and Sustainable Agriculture for Resilience (CAISAR)

Methodology for GHG accounting:

The Ex-Ante Carbon Balance Tool (EX-ACT) has been developed by the Food and Agriculture Organization of the United Nations (FAO) to evaluate impacts of interventions in the Agriculture, Forestry and Other Land Use (AFOLU) sector on greenhouse gas (GHG) emissions. EX-ACT provides estimates of the mitigation potential of public or private investment projects, policies and national-level programs. It helps the decision makers to understand whether the planned agricultural interventions contribute to meaningful GHG emissions mitigation to meet their NDC objectives.

EX-ACT[1] calculations are primarily based on land-use data. GHG emissions for implementation of farm operations, inputs, transport, and irrigation systems are based on Lal (2004)[2]. These references provide EX-ACT with recognized default values for emission factors and carbon values, the so-called Tier 1 level of precision. The EX-ACT tool[3] calculates changes in carbon stocks and GHG emissions including carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), which once converted to CO2 equivalent are used to derive the carbon balance that indicates the impact of the project; positive carbon balance indicates that the project results in higher emissions, while negative carbon balance indicates that project contributes to emissions reduction.

The evaluation assesses how the impacts of an intervention compared to the business as usual (BAU) scenario. The calculator requires data for 3 specific points in time: initial situation, with-project scenario, without-project or business-as-usual (BAU). Upfront work is required to determine how best to model the project activities or intervention, the kind of primary or secondary data that needs to be collected, and the assumptions that will underpin the modeling. This process takes into consideration technical specificities, conversations with national staff to determine current and future projections, literature reviews to assess availability of Tier 2 or 3 coefficients to improve the accuracy of the assessment. All these aspects are discussed below to ensure a clear and transparent understanding of the assessment done for CAISAR.

Project Objective:
The project objective is to increase climate adaptation, mitigate the negative impact of extreme climate events, and improve livelihoods of smallholder farmers and vulnerable rural communities in four provinces of Cambodia. CAISAR's Theory of Change is premised on the experience that addressing the complex impacts of climate change on rain-fed and irrigated agriculture requires action at three levels; farm level; irrigation scheme level; and at the national level for creating a strong institutional base and an enabling environment. The project is expected to impact 500,000 beneficiaries directly (direct beneficiaries).

The project is structured as three components:

- Component 1: Farm-level adaptation and resilience.
- Component 2. Upgrading and climate-proofing water infrastructure for increased resilience.

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[1] The current version of EX-ACT is based on *the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006) and *the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (IPCC 2014), complemented by other scientific research.
[2] Emission factors for the fishery sector are derived from Parker & Tyedmers (2014), Sciortino (2010), Winther et al. (2009) and Irribaren et al. (2010 & 2011). Soil carbon stock in mangroves is complemented by the review from Atwood et al. (2017).
[3] The tool consists of seven modules that allow analysis of a range of agricultural and forestry activities including crop production, land rehabilitation, forest management, livestock, and grassland production systems among others.

- Component 3. Strengthened institutional and regulatory capacity for low-emission climate-resilient development pathways.

Several rounds of stakeholder consultations between 2022 and 2024 informed the development of baseline and additionality for GHG analysis, in addition to literature reviews. MOWRAM's CAISAR team conducted field surveys between October-November 2023, and had discussions with government officials, commune representatives and farmers. Prior to this, WAPCOS Limited led feasibility assessment and conducted field surveys, including an agronomy survey in 2022. Finally, the baseline data and additionality assumptions were validated through literature review and the sources are outlined throughout Annex 22. Agronomy survey and CAISAR team consultations captured data, by irrigation scheme, on number of harvests per year, crops cultivated and associated area, farming calendar, yields, farm gate prices, water use and irrigation practices, etc. which informed both EX-ACT and EFA analyses. For main canals, secondary canals, feeder canals, flood protection dikes, and secondary drains, the length, width and breadth (see section on infrastructure investments) are derived from the feasibility and design studies conducted by MOWRAM's CAISAR Team, with support from AIIB and IFAD (Annex 2, Section 5.1 Subcomponent 2.1 & 2.2).

These data sources establish the foundation for constructing baseline scenarios against which project additionality is assessed. For each activity area, specific methodologies were employed to determine both the current practices and the business-as-usual trajectory that would occur without project intervention. Table 1A lists the project activities from each component which informed the EX-ACT analysis i.e., sequestration, reduction and or avoidance of GHG emissions that result from the implementation of the activities. The assumptions and data used are presented in subsequent sections; in all cases, it is assumed that 80% of the project's target will be met at the end of the implementation period.

Table 1A: Project activities considered under EX-ACT analysis

Nature of changes in cropping system and water use due to project activities, and anticipated impacts on GHG emissions (this table explains assumptions underpinning additionality)	**Reference**	**Ex-ACT Module**
Annual crops and livestock (poultry, fish) The activity will focus on enabling investments and market linkages of farmers, farmer groups, agricultural cooperatives and associated MSMEs in vegetables, native chicken and fish values. • Within the flooded rice cropping systems, the project will introduce annual crops such as fruit and leafy vegetables as double crops in 4117.8 hectares of land to support agricultural diversification and increase household income / create employment opportunities for young people, thereby strengthening climate resilience of livelihoods. In general, increasing cropping seasons and intensity contributes to increased GHG emissions. This cropping system transformation also incorporates reduced tillage and utilizes low-carbon inputs to increase cropping intensity – these practices can help avoid some of the increase in GHG emissions. However, this simultaneously occurs with increased fertilizer inputs (autonomous purchase by farmers) and increased residue generation which increases GHG emissions. As Table 6 indicates, there is very minimal annual cropping in these provinces at baseline. In the absence of CAISAR investments in irrigation as well as complementary support to farmers, the assumption is that farmers will not cultivate annual crops owing to poor access to water, quality seeds and commodity markets.	Concept Note / Full proposal / Project Team discussions	Cropland/Inputs and Investments/Grassland management/Fisheries and Aquaculture

Nature of changes in cropping system and water use due to project activities, and anticipated impacts on GHG emissions (this table explains assumptions underpinning additionality)	**Reference**	**Ex-ACT Module**
• Owing to CAISAR investments, the number of poultry managed by farmers will expand from a baseline of 192,500 (both broiler and layer chickens) to 385,000 through value chain development interventions. This will contribute to increased GHG emissions. In the absence of CAISAR investments, the number of poultry is assumed to remain constant; at the most, there would be replacement of any birds lost owing to sale or due to morbidity (e.g., heat stress). • The project additionality assumption is that area of fishponds will expand (from 19.25 hectares to 57.75 hectares) owing to better water management and value chain development interventions. Conversely, the area of fishponds will remain the same, particularly due to poor water availability and droughts, in the absence of CAISAR investments. This will contribute to increased GHG emissions, particularly owing to the use of feeds.		
Flooded rice cultivation The activity will focus on 22,046 ha irrigation command area and 30,232 ha of cultivated flooded rice (Table 3). Baseline assessment established a cropping intensity of 137 percent, with predominantly continuously flooded rice cultivation practices (Table 4). In the without-project scenario, a conservative 1.5 percent autonomous adoption rate of improved practices is assumed based on regional technology diffusion studies (Ramírez Villegas et al., 2021), reflecting the limited natural uptake (of intermittent flooding, better residue practices, improved fertilizer management, appropriate cultivation timing, etc.) that would occur without CAISAR investments. The additionality of the project is demonstrated by the increase in cropping intensity to 192 percent and the implementation of practices that overcome significant technical, financial, and knowledge barriers (to climate-resilient production) present in the baseline scenario i.e., owing to the investments in upgrading and climate-proofing water infrastructure, farm-level adaptation and resilience support (including awareness of intermittent flooding), improved market access, and agro-meteorological information and services. Farm-level activities underpinned by and will benefit from increased access to and use of climate information and advisory services for climate-responsive water-use and crop planning by farmers and water user groups. The activity will introduce farmers to climate-resilient technologies and sustainable practices, including: • Transitioning continuously flooded rice fields (i.e., 80 percent of the baseline cultivated area) to intermittently flooded rice with multiple drainage systems using Alternate Wetting and Drying (AWD). AWD as a management approach helps reduce the number of flooding days, conserve water and reduce GHG emissions from rice. • Conversion of rainfed fields (i.e., 20 percent of the baseline cultivated area) to intermittently flooded and multiple drainage irrigated systems (employing AWD) and improving water efficiency before the cultivation period (i.e., moving from non-flooded pre-season > 180 days to non-flooded pre-season < 180 days to enable rice farming in	Concept Note / Full proposal / Project Team discussions	Cropland/ Inputs and Investments

Nature of changes in cropping system and water use due to project activities, and anticipated impacts on GHG emissions (this table explains assumptions underpinning additionality)	Reference	Ex-ACT Module
two seasons). This supports yield stability, water conservation, and reduction / avoidance of GHG emissions from rice. • Optimizing fertilizer management through reduced nitrogen use (by 16 percent) and increasing organic fertilizer (by 100 percent). This also reduces GHG emissions in fertilizer input use. • Enhancing straw residue management in rice cropping systems i.e., reducing burning by 15 percent and increasing straw export by 45 percent (through recycling and circular management) is estimated to reduce overall GHG emissions. • Replacement of diesel pumps with solar irrigation in 15,000 ha of flooded rice systems or about 69 percent of cultivated area aligned with cropping intensity is expected to reduce GHG emissions.		
Resilient rural roads • Construction and rehabilitation of 86.75 kms of roads (width of 5 meters), 78.1 kms of which with Double Bituminous Surface Treatment (DBST) and 8.6 kms as Reinforced Concrete (RC) roads. This activity will also involve conversion of annual fallow land to construct roads. This will contribute to increased GHG emissions (but of course contributes to improved adaptive capacity and resilience of livelihoods, as explained in the Funding Proposal).	Concept Note/ Full proposal / Project Team discussions	Inputs and Investments
Modernization of irrigation scheme and ponds & Flood-proofing and drainage improvements Infrastructure investments under Component 2 are tightly linked with Component 1; it will focus on rehabilitating and modernizing infrastructure, including irrigation canals, drainage structures, ponds, and flood-protection (embankment) works in order to provide high-efficiency climate-resilient irrigation systems for adapting to increased risks of both floods and droughts. The activity will focus on constructing or rehabilitating 113.4 kms of both main canals and secondary canals as well as 1.6 kms of flood-protection dikes, 2.35 kms of drains – where these structures are constructed or lined with concrete and there is land use change (from fallow or cropped land to canals), this associated with increased GHG emissions (but of course contributes to improved adaptive capacity and resilience of livelihoods, as explained in the Funding Proposal).	Concept Note/ Full proposal / Project Team discussions	LUC/Inputs and Investments

EX-ACT differentiates between two time periods: project implementation phase and capitalization phase. In this analysis, following recommendations of the IPCC[4], we consider an overall 20-year timeframe for implementation and capitalization phase. The implementation phase is the period during which the project activities are carried out; this spans 7 years for CAISAR. Yet, the period covered by the analysis does not necessarily end with the termination of the active project intervention. Further changes may occur as the result of the interventions (project activities) well after the termination of project activities, such as changes in soil carbon content or biomass. This period

[4] IPCC recommends considering the timeframe between transitions states of natural systems and the period necessary to reach a new equilibrium for carbon stocks and suggest applying a 20-year long time frame.

defines the capitalization phase, the benefits generated by the project will continue to capitalize for 13 more years to reach the 20-year period. In the specific case of soil organic carbon, a constant rate over a period of 20 years from the year of planting to reach the new equilibrium is assumed. The analysis further assumes the dynamics of change (from "without" (BAU) to "with-project") to be linear over the duration of the project.

Main Results of the EX-ACT Analysis:
Overall, results show a positive environmental impact due to the implementation of the project's activities, quantified at a total carbon balance of **-1,006,507.43 tCO2-eq over 20 years**. This would amount to a carbon balance of **-2.3 tCO2-eq per hectare per year** (Figure 1, Figure 2). Details on different assumptions, references and other information are provided in the Computation of data in EX-ACT section below. The carbon balance disaggregated by different activities are as follows (Table 1B).

Table 1B: Summary of results from EX-ACT analysis

	Activity	**Total carbon balance (tCO2-eq)**
1	**Other land use over 20 years**	**1,231**
	Without project (fallow land)	0
	"With project" (conversion of annual fallow into roads and conversion of flooded rice fields into canals for irrigation / drainage / dikes)	1,231
2	**Annual cropping systems over 20 years**	**40,876**
	Without Project (no annual crops)	0
	"With project" (introducing annual crops)	40,876
3	**Flooded rice cropping systems over 20 years**	**- 1,179,414**
	Without Project (conventional water and soil management practices)	3,034,297
	"With project" (AWD, water use efficiency before cultivation, residue management)	1,854,883
4	**Livestock (poultry) over 20 years**	**71,138**
	Without Project	4,019
	"With project" (improving/scaling poultry production)	75,157
5	**Livestock (fish) over 20 years**	**1,389**
	Without Project	629
	"With project" ((improving/scaling fish production)	2,018
6	**All other investments: Inputs management and Infrastructure Investments**	**58,272**
	Without Project (diesel pumps, unsustainable fertilizer management, no infrastructure, no irrigation canals, dikes or roads)	401,518
	"With project" (solar powered irrigation, improved fertilizer management, irrigation canal infrastructure and investments, flood-protection dikes, drainage canals and roads, roads and canals,)	459,790

Figure 1: Snapshot of results from CAISAR EX-ACT analysis

DETAILED RESULTS

Project name	CAISAR Cambodia	**Project duration (in years)**		**Total area (ha)**	22,103	**Global warming potential**
Continent	South-eastern Asia	Implementation Phase	7	Mineral soil	25,398	CO_2 1
Country	Cambodia	Capitalization Phase	13	Organic soil	0	CH_4 28
Climate	Tropical	Total Duration of Accounting	20	Waterbodies	-3,294	N_2O 265
Moisture	Moist					

GROSS FLUXES — In tCO2-e over the whole period analysis | SHARE PER GHG OF THE BALANCE — In tCO2-e over the whole period analysis (Tier 2 Specific GHG fluxes) | AVERAGE ANNUAL EMISSIONS — In tCO2-e/yr (Tier 2 Annual emissions)

PROJECT COMPONENTS		WITHOUT	WITH	BALANCE	CO2 BIOMASS	CO2 SOIL	N_2O	CH_4	ALL NON-AFOLU EMISSIONS*	WITHOUT	WITH	BALANCE
Land use changes	Deforestation	0	0	0	0	0	0	0		0	0	0
	Afforestation	0	0	0	0	0	0	0		0	0	0
	Other land-use	0	1,231	1,231	1,006	224	0	0		0	62	62
Cropland	Annual	0	40,876	40,876	0	16,359	5,651	18,866		0	2,044	2,044
	Perennial	0	0	0	0	0	0	0		0	0	0
	Flooded rice	3,034,297	1,854,883	-1,179,414	0	0	-6,326	-1,173,088		151,715	92,744	-58,971
Grasslands & Livestock	Grasslands	0	0	0	0	0	0	0		0	0	0
	Livestock	4,019	75,157	71,138			-63	71,202		201	3,758	3,557
Forest mngt.		0	0	0	0	0	0	0		0	0	0
Inland wetlands		0	0	0	0	0	0	0		0	0	0
Coastal wetlands		0	0	0	0	0	0	0		0	0	0
Fisheries and aquaculture		629	2,018	1,389	0	0	563	0	826	31	101	69
Inputs & Invest.		401,518	459,790	58,272		0	28,041		30,232	20,076	22,989	2,914
Total emissions, tCO2-e		**3,440,462**	**2,433,955**	**-1,006,507**	**1,006**	**16,583**	**27,865**	**-1,083,020**	**31,057**	**172,023**	**121,698**	**-50,325**
Total emissions, tCO2-e/ha		**155.7**	**110.1**	**-45.5**	**0.0**	**0.8**	**1.3**	**-49.0**	**1.4**			
Total emissions, tCO2-e/ha/yr		**7.8**	**5.5**	**-2.3**	**0.0**	**0.0**	**0.1**	**-2.4**	**0.1**			

+ = Source / - = Sink
Results presented here include GHG fluxes on mineral and organic soils
See further down for detailed results on organic soils
* Includes fisheries, acquaculture and inputs & investments that are not included in the AFOLU definition.

Uncertainty level	tCO2-e/yr	Percent
WITHOUT	172,023	17%
WITH	121,698	21%
BALANCE	-50,325	18%

Figure 2: Disaggregated Carbon balance of CAISAR activities from EX-ACT analysis

GROSS FLUXES

In tCO2-e over the whole period analysis

PROJECT COMPONENTS		WITHOUT	WITH	BALANCE
Land use changes	Deforestation	0	0	0
	Afforestation	0	0	0
	Other land-use	0	1,231	1,231
Cropland	Annual	0	40,876	40,876
	Perennial	0	0	0
	Flooded rice	3,034,297	1,854,883	-1,179,414
Grasslands & Livestock	Grasslands	0	0	0
	Livestock	4,019	75,157	71,138
Forest mngt.		0	0	0
Inland wetlands		0	0	0
Coastal wetlands		0	0	0
Fisheries and aquaculture		629	2,018	1,389
Inputs & Invest.		401,518	459,790	58,272
Total emissions, tCO2-e		**3,440,462**	**2,433,955**	**-1,006,507**
Total emissions, tCO2-e/ha		**155.7**	**110.1**	**-45.5**
Total emissions, tCO2-e/ha/yr		**7.8**	**5.5**	**-2.3**

+ = Source / - = Sink
Results presented here include GHG fluxes on mineral and organic soils
See further down for detailed results on organic soils
* Includes fisheries, acquaculture and inputs & investments that are not included in the AFOLU definition.

Computation of Data in EX-ACT:
This section presents the rationale of how activities were considered in the analysis and data used. Furthermore, it includes the activities that have been excluded from the analysis and the rationale for such exclusion and recommendations for the refinement of the analysis.

General Approach:
Default Tier 1 values for Soil Organic Carbon (SOC) as provided in the EX-ACT tool is used for this analysis as the values for Soil Organic Carbon (SOC) content retrieved from the Global Soil Organic Carbon (GSOC) map via Earthmap for the different provinces of the project area are very close to Tier 1 values.

Table 2: Reference SOC levels at the province level

Province	Pursat	Kampong Chhnang	Kampong Speu	Kandal
SOC (tC/ha)	38	29	31	42

According to the project area defined, the climate in the project area is Tropical Moist.

Information for Project Activities:

Flooded rice cropping systems

Area under key rice crop seasons and cropping intensity patterns are presented in Table 3.

Table 3: Cropping intensity patterns baseline and "with project" scenarios

Baseline		With Project	
Total irrigation command area (Ha)	22,046	Total irrigation command area (Ha)	32,056
Early wet season rice	13,777	Early wet season rice	22,889
Medium wet season rice	4,925	Medium wet season rice	2,862
Late wet season rice	2,606	Late wet season rice	1,497
Dry season rice	8,924	Dry season rice	11,155.6
Leafy vegetables	0	Leafy vegetables	2,058.9
Fruit vegetables	0	Fruit vegetables	2,058.9
Total cultivated area	30,232	Total cultivated area	42,521
Cropping Intensity (%)	137 %	Cropping Intensity (%)	192 %

Baseline cropping patterns and practices were established through field surveys and stakeholder consultations and IRRI documents (Table 1A). Additionality was assessed by identifying specific changes in water management, residue handling, and cropping intensity that would not occur in the without-project scenario, thus representing additional climate benefits attributable to CAISAR.

Based on the baseline cropping patterns, five different rice cropping systems are defined to perform the GHG assessment in EX-ACT: wet season rainfed crop, early, medium and late wet season irrigated crop, and dry season irrigated crop. In the baseline, 25 percent of all wet season rice is assumed to be rainfed, and remaining 75 percent is assumed to be irrigated crop. 100 percent of the dry season rice is assumed to irrigated. The with-project scenario is developed based on the assumption that the project will attain 80 percent of its targets. This scenario involves the transformation of wet season rainfed rice into irrigated rice and the enhancement of management practices within all five defined rice cropping systems.

The with-project situation is constructed based on a global generalized estimate of technology transfer and adoption of different agricultural practices (Ramírez Villegas et al., 2021). Accordingly, it is assumed that 1.5 percent of the project targeted area will come under improved flooded-rice management practices, even in the absence of the CAISAR project as there are several other initiatives, both private and public that target similar activities and interventions in the region. This assumption provides a conservative additionality estimate for the project.

Table 4 provides an overview of allocation of hectares per defined rice cropping systems under the five relevant scenarios for the carbon balance estimation.

Table 4: Summary of allocated hectares per flooded rice system under the three relevant scenarios

	Start	**Without**	**With**
Conventional Rainfed Wet Season rice	5,327	4,792.6	1,115.56
Conventional Irrigated Early Wet Season rice	10,332.75	9,558	4,577.8

Conventional Irrigated Medium Wet Season rice	3,693.75	3,417	572.4
Conventional Irrigated Late Wet Season rice	1,954.5	1,808	299.4
Conventional Dry Season rice	8,924	8,390	1,115.6
Improved Early Wet Season rice	0	775.0	18,311.2
Improved Medium Wet Season rice	0	277.0	2,289.6
Improved Late Wet Season rice	0	146.6	1,197.6
Improved Irrigated Dry + Rainfed Season rice	0	1,068.8	8,924.5

The baseline water management practices in rice cultivation were documented through surveys and consultations (Table 1A). Additionality of AWD implementation was determined by comparing adoption rates in the with-project scenario against projected rates in the without-project scenario, demonstrating the additional climate benefits specifically attributable to CAISAR's interventions.

The water management practices assumed for the cropping systems in the baseline and with-project scenario are as follows: the wet season rainfed crop is rainfed, while the wet season irrigated, and dry season irrigated crops are continuously flooded. In the with-project scenario, the introduction of AWD practices leads to a shift in water management, transitioning all the cropping systems to irrigated with multiple drainage periods.

Based on the baseline characterization and the implementation of project activities, the water regime before cultivation for rainfed rice during the wet season is assumed to be "non-flooded pre-season >180 days” [5] while for all the other rice cropping systems, it is assumed to be "non-flooded pre-season <180 days”[6].

In the baseline, all the cropping systems are assumed to have a 130-day cultivation period. In the with-project scenario the cultivation period is assumed to be 80 days reducing the number of flooding days in the crop cycle.

In both the baseline and with-project scenarios, the assumed residue management practices for the cropping systems are as follows:

- Straw exported (30%): This practice is aligned with the Wet Season Rainfed Crop. The assumption here is that households cultivating only rainfed rice are likely to store straw for dry-season livestock feeding.
- Straw burnt (30%): This practice is aligned with the Irrigated Dry Season Crop. The assumption is that straw is burnt during the dry season to cope with potential labor shortages.
- Straw incorporated (40%): This practice is aligned with the remaining Irrigated Wet Season Crop, and it is assumed that straw is incorporated into the soil more than 30 days before the next season.

In the with-project scenario, it is assumed that project activities will have the following effects:

- Reduce straw burnt to 10%.
- Reduce the amount of straw incorporated by 15%.
- Increase the export of straw for circular management approaches, resulting in an increase of straw exported from 30% to 65%.

[5] If rice is planted once a year and the field is not flooded in the non-rice growing season, the preseason water regime is classified as ‘non flooded pre-season >180 days.

[6] Rice is planted more than once a year, but there is more than one month of fallow time between the two seasons, ‘non-flooded pre-season <180 days’ usually implies pre-season drainage.

Changes in irrigation practices and straw management practices reduce the emissions in flooded rice systems by **-1,179,414 tCO2-eq over 20 years** (Figure 3).

Figure 3: Carbon balance of flooded rice systems

3.3.2. Flooded rice systems remaining flooded rice systems

		Management options for water regime in flooded-rice				Flooded-rice area (ha)					Total emissions (tCO2-e)		
User notes	Cultivation period (days)	During Cultivation period	Before Cultivation period	Organic amendment	Yield (t/ha/yr)	Start	Without	*	With	*	Without	With	Balance
Conventional Rainfed Wet Season rice	130	Rainfed, wet season (regular rainfed)	Non flooded pre-season >180 d	Straw incorporated long		5,327	4,793	D	1,116	D	335,820	127,326	-208494.3834
Conventional Irrigated Early Wet Season rice	130	Irrigated, Continuously flooded	Non flooded pre-season <180 d	Straw burnt		10,333	9,558	D	4,578	D	956,378	551,023	-405354.9945
Conventional Irrigated Medium Wet Season rice	130	Irrigated, Continuously flooded	Non flooded pre-season <180 d	Straw exported		3,694	3,417	D	572	D	307,765	99,353	-208412.3366
Conventional Irrigated Late Wet Season rice	130	Irrigated, Continuously flooded	Non flooded pre-season <180 d	Straw exported		1,955	1,808	D	299	D	162,850	52,316	-110533.5381
Conventional Dry Season rice	130	Irrigated, Continuously flooded	Non flooded pre-season <180 d	Straw incorporated long		8,924	8,390	D	1,116	D	1,213,151	354,951	-858200.2849
Improved Early Wet Season rice	80	Irrigated, Multiple drainage periods	Non flooded pre-season <180 d	Straw exported		0	775	D	18,311	D	12,580	297,243	284662.8987
Improved Medium Wet Season rice	80	Irrigated, Multiple drainage periods	Non flooded pre-season <180 d	Straw exported		0	277	D	2,290	D	4,497	37,167	32669.69041
Improvedl Late Wet Season rice	80	Irrigated, Multiple drainage periods	Non flooded pre-season <180 d	Straw burnt		0	147	D	1,198	D	3,570	29,169	25598.79614
Improved Irrigated Dry + Rainfed Season rice	105	Irrigated, Multiple drainage periods	Non flooded pre-season <180 d	Straw incorporated long		0	1,069	D	8,924	D	36,666	306,158	269491.1858
	102	Please select	Please select	Please select		0	0	D	0	D	0	0	0
					Total (ha)**	30,232	30,232		38,404				

Please check areas!

Please confirm total area of flooded rice remaining flooded rice (ha)	22,045		
Total flooded-rice systems (tCO2-e)	3,034,297	1,854,883	-1179413.896

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.
**In case of flooded rice the total area considered for emissions calculations may be greater than actual total land under flooded rice if multicropping seasons are in place. It is key to provide the actual area under flooded rice in cell K122 to ensure correct area aggregation in the results.

The assessment of water management is further refined using Tier 2 values. The Tier 2 estimates for Scaling Factors Water Regime during cultivation period are retrieved from the meta-analysis by *Jiang et al.*, *(2019)* which included several South Asian and South-East Asian Studies as well. *Jiang et al.*, *(2019)* propose to revise the IPCC estimates on scaling factors (SFs) for multiple-drainage periods from 0.55 to 0.36 based on their meta-analysis findings. There is a significant increase in mitigation potential when using Tier 2 data in flooded rice systems with improved water management practices. The carbon balance estimated using Tier 1 default value vs Tier 2 refined value is presented in Table 5a.

Table 5a: Tier 1 vs Tier 2 data and associated carbon balance in flooded rice systems alone

Tier-1 Data (SF for multiple drainage periods = 0.55)		
Carbon Balance Over 20 years	**-860,697**	**tC02-eq**
Tier-2 Data (SF for multiple drainage periods = 0.36)		
Carbon Balance Over 20 years	**-1,179,414**	**tC02-eq**

<u>Sensitivity analysis: Adoption rates of intermittently flooded rice with multiple drainage systems using AWD</u>

The main project scenarios were computed assuming an 80 percent achievement of project's targets. To further account for potential variations in farmers' adoption rates of intermittent flooding, a further sensitivity analysis is performed to understand the impact of such adoption rates on overall project emissions, and particularly those from rice cropping systems. This sensitivity analysis aims to provide insights into the project's impact under different implementation scenarios. The resultant carbon balance for these scenarios is presented below (Table 5b).

In the baseline, all the cropping systems are assumed to have a 130-day cultivation period.

- **Alternate Scenario 1:** Scenario 1 presents a mixed adoption assumption across the project area:
  In 75% of the total project area:
    - 70% of farmers adopt multiple/intermittent drainage techniques.
    - The cultivation period is reduced to 80 days.

  In the remaining 25% of the project area:
    - 100% of farmers implement single drainage.
    - The cultivation period is 105 days.

This scenario reflects a realistic adoption pattern where most of the area sees significant changes in both drainage techniques and cultivation period a smaller portion of the area adopts a less intensive change, possibly due to local conditions or farmer preferences.

- **Alternate Scenario 2:** Scenario 2 presents a more conservative adoption assumption across the project area.

In 75% of the total project area:
- 50% of farmers adopt multiple/intermittent drainage techniques.
- The cultivation period is reduced to 80 days.

In the remaining 25% of the project area:
- 50% of farmers implement single drainage.
- 50% of farmers continue with continuously flooded practices.
- The cultivation period remains at 105 days.

This scenario allows for analysis of project outcomes under more challenging adoption circumstances, accounting for potential resistance to change or implementation difficulties.

Table 5b: Sensitivity analysis based on AWD adoption rates

Scenario	**Carbon Balance (tCO2-eq)**
Scenario – 1 (More realistic)	**-783,083.76**
Scenario – 2 (More conservative)	**-454,027.16**

Annual cropping systems

Based on Table 6, in both the baseline and with-project scenarios, no annual crop cultivation is considered. In the with-project scenario, introduction of annual crops is assumed to be integrated into the double cropping systems within flooded rice. This approach prevents any double counting of land-use related emission factors. Summary of the area under cultivation of annual crops as estimated for GHG assessment is provided in Table 6, and as noted earlier, the areas are calculated based on the assumption that the project can achieve 80 percent of its targets.

In the with-project scenario, management practices of annual crops cultivation are assumed as follows,
- Tillage: “Reduced” tillage is considered which is deemed suitable considering the scale of land under consideration.
- Carbon input: “Low[7]” carbon input is assumed as the project targets annual crops such as low residue yielding crops such as leafy as well as fruit vegetables in double cropping systems.

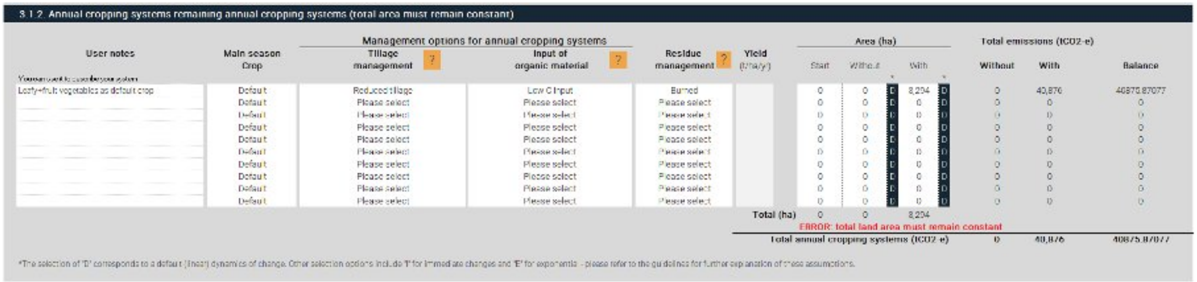
Introduction of annual crops along with their associated management practices leads to increased emissions with a carbon balance of **40,876 tCO2-eq** over 20 years (Figure 4).

Table 6: Summary of allocated hectares per annual crops under the three relevant scenarios

	Start (ha)	**Without (ha)**	**With (ha)**
Leafy + Fruit vegetables	0	0	3,294.24

Figure 4: Carbon balance of annual cropping systems

[7] Low carbon input is defined as followed in EX-ACT: "Low C input cropland systems are defined by one of the following conditions: (1) The crop residues of annual crops are removed or burnt without using organic amendments (e.g. manure) or (2) Low residue yielding crops are cultivated (e.g., cotton, green maize, vegetables, tobacco) or frequent rotation with bare fallow without organic amendments, cover crops/green manures, and mixed crop/grass systems or (3) Annual crops with no mineral fertilization or N-fixing crops without irrigation, cover crops/green manures, vegetated fallows, high residue yielding crops and mixed crop/grass systems"



3.1.2. Annual cropping systems remaining annual cropping systems (total area must remain constant)

User notes	Main season Crop	Tillage management	Input of organic material	Residue management	Yield (t/ha/y)	Area (ha) Start	Without	*	With	*	Total emissions (tCO2-e) Without	With	Balance
Leafy+fruit vegetables as default crop	Default	Reduced tillage	Low C input	Burned		0	0	D	8,204	D	0	40,876	40875.87077
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
	Default	Please select	Please select	Please select		0	0	D	0	D	0	0	0
					Total (ha)	0	0		8,204				
					Total annual cropping systems (tCO2-e)						0	40,876	40875.87077

ERROR: total land area must remain constant

*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

Livestock and fish

<u>Baseline livestock and fishery production systems were documented through comprehensive surveys (Table 1A). Additionality was assessed by identifying productivity improvements and management changes that would only occur through CAISAR's value chain development activities, beyond baseline production systems.</u>

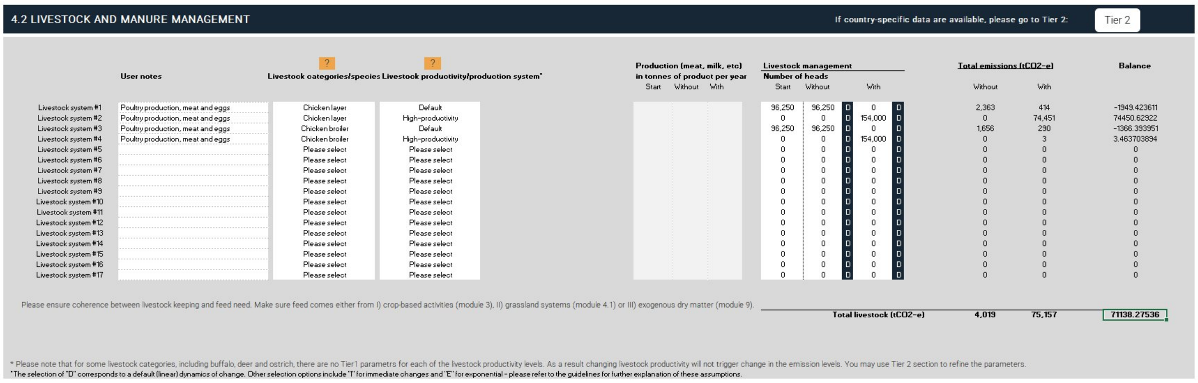
As shown in Table 7, the total number of poultry (head count) remains constant in both baseline and without-project scenarios for the two main livestock types addressed by the project: layer chicken and broiler chicken that are associated with egg and meat production. In these scenarios, the livestock production systems are characterized as low productivity. In the with-project scenario, the production systems are expected to transition from low to high productivity (for instance, the mortality rate reduces from 20% to 5%). The total number of poultry heads in this scenario is calculated assuming the project achieves 80 percent of its targets.

Table 7: Summary of poultry under the three relevant scenarios

	Start	**Without**	**With**
Poultry (Total Nos)	192,500	192,500	308,000
Chicken layer (eggs)	96,250	96,250	154,000
Chicken broiler (meat)	96,250	96,250	154,000

This transition from low to high productivity alongside increased number of heads leads to an increase in emissions with a carbon balance of **71,138 tCO2-eq** over 20 years (Figure 5).

Figure 5: Carbon balance of livestock (poultry) management



4.2 LIVESTOCK AND MANURE MANAGEMENT

If country-specific data are available, please go to Tier 2: Tier 2

	User notes	Livestock categories/species	Livestock productivity/production system*	Production (meat, milk, etc) in tonnes of product per year Start	Without	With	Livestock management Number of heads Start	Without		With		Total emissions (tCO2-e) Without	With	Balance
Livestock system #1	Poultry production, meat and eggs	Chicken layer	Default				96,250	96,250	D	0	D	2,363	414	-1949.423611
Livestock system #2	Poultry production, meat and eggs	Chicken layer	High-productivity				0	0	D	154,000	D	0	74,451	74450.62922
Livestock system #3	Poultry production, meat and eggs	Chicken broiler	Default				96,250	96,250	D	0	D	1,656	290	-1366.393951
Livestock system #4	Poultry production, meat and eggs	Chicken broiler	High-productivity				0	0	D	154,000	D	0	3	3.463703894
Livestock system #5		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #6		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #7		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #8		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #9		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #10		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #11		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #12		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #13		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #14		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #15		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #16		Please select	Please select				0	0	D	0	D	0	0	0
Livestock system #17		Please select	Please select				0	0	D	0	D	0	0	0
										Total livestock (tCO2-e)		4,019	75,157	71138.27536

Please ensure coherence between livestock keeping and feed need. Make sure feed comes either from I) crop-based activities (module 3), II) grassland systems (module 4.1) or III) exogenous dry matter (module 9).

* Please note that for some livestock categories, including buffalo, deer and ostrich, there are no Tier1 parametrs for each of the livestock productivity levels. As a result changing livestock productivity will not trigger change in the emission levels. You may use Tier 2 section to refine the parameters.
*The selection of "D" corresponds to a default (linear) dynamics of change. Other selection options include "I" for immediate changes and "E" for exponential - please refer to the guidelines for further explanation of these assumptions.

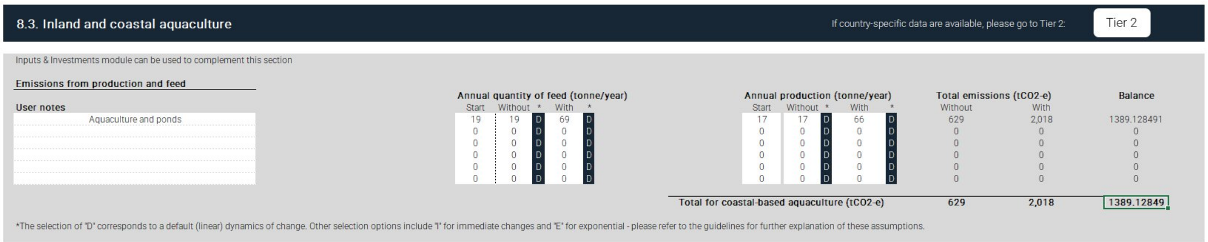
As shown in Table 8, the total area under fishponds remain constant in both baseline and without-project scenarios. In the with-project scenario, there is an increase in the total fishpond area as well as in feed usage and production levels. For the with-project scenario, total feed consumption and production are calculated assuming the project achieves 80 percent of its targets.

Table 8: Summary of fishponds, feed, and production under the three relevant scenarios

	Start	Without	With
Fishponds (ha)	19.25	19.25	46.2
Feed (tonnes/year)	19.25	19.25	69.3
Production (tonnes/year)	17.325	17.325	65.835

The increase in feed and production slightly increases the emissions with a carbon balance of **1,389 tCO2-eq** over 20 years (Figure 6).

Figure 6: Carbon balance of fisheries management



<u>**Inputs**</u>

Baseline inputs usage was determined through field surveys and stakeholder consultations (Table 1A). Additionality was assessed by quantifying the emission reductions from solar irrigation and optimized fertilizer management that would only occur with project support, beyond the business-as-usual trajectory.

<u>**Inputs – Fertilizers**</u>

In the baseline and with-project scenarios, there is a higher consumption of Nitrogen (90 kg per ha) and a lower utilization of organic fertilizer (1000 kg per ha). However, in the with-project scenario, there is a reduction of 15 kg in Nitrogen use (75 kg per ha), and an increase of 1000 kgs in organic fertilizer application (2000 kg per ha). Table 9 provides an overview of the estimated fertilizer quantities for all the three - baseline, with-project, and with-project scenarios. Emissions from using different synthetic and organic fertilizers that include Nitrogen, Phosphorous, Potassium and organic manure or compost are higher in the baseline scenario (297,704 tCO2-eq) as compared to the with-project scenario (301,499 tCO2-eq) with an overall carbon balance of **3,795 tCO2-eq** over 20 years (Figure 7).

The calculations for diesel consumption in both the baseline and without-project scenarios rely on the following assumptions (Table 9):

- 80 percent of all wet season and dry season rice crops utilize diesel.
- An average usage of 80 liters of diesel per hectare for water pumping.

<u>**Inputs – Solar irrigation**</u>

In the with-project scenario, the activities focus on transitioning 15,000 ha from diesel pumps to solar pumping systems. It is assumed that 80 percent of this target will be achieved. The 15,000 ha are assumed to operate within a double cropping system, aligning with cropping intensity. The shift to solar pumping systems results in substantial reduction in diesel consumption, ultimately leading to a carbon balance of **-44,841 tCO2-eq** over 20 years associated with energy consumption (Figure 8).

Table 9: Overview of different fertilizers and diesel used under the three relevant scenarios

Flooded rice			
	Start	**Without**	**With**
N in tonnes	2,293.24	2,293.24	1,985.87
P in tonnes	503.28	503.28	419.37
K in tonnes	679.81	679.81	602.69
Compost (N in tonnes)	151.16	151.16	307.20
Diesel (in m3)	1,934.85	1,934.85	921.83
Annual Crops			
	Start	**Without**	**With**
N in tonnes	0	0	16.47
P in tonnes	0	0	16.47
K in tonnes	0	0	16.47
Compost (N in tonnes)	0	0	0.0

Figure 7: Carbon balance of fertilizer inputs

9.1 INPUTS (liming, fertilizers, pesticides)

If country-specific data are available, please go to Tier 2: Tier 2

Fertilizers	Amount applied per year (in tonne)			Total emissions at field level (tCO2-e)				Emissions from production, transportation, storage and transfer (tCO2-e)		**Total emissions (tCO2-e)**		
				CO2 emissions		N2O emissions						
	Start	Without	With	Without	With	Without	With	Without	With	Without	With	**Balance**
Lime application												
Limestone (tonnes per year)	0.00	0.00	0.00	0	0	-	-	0	0	0	0	0
Dolomite (tonne per year)	0.00	0.00	0.00	0	0	-	-	0	0	0	0	0
Not-specified (tonnes per year)	0.00	0.00	0.00	0	0	-	-	0	0	0	0	0
Synthetic fertilizers												
Urea (tonnes of Urea per year)	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0
Synthetic N-fertilizers other than Urea (tonnes of N per year)	0.00	0.00	16.47	-	-	0	1,188	0	1,295	0	2,484	2483.795193
Phosphorus (tonnes of P2O5 per year)	503.28	503.28	435.84	-	-	-	-	7,381	6,565	7,381	6,565	-815.99012
Potassium (tonnes of K2O per year)	679.81	679.81	619.16	-	-	-	-	7,478	6,928	7,478	6,928	-550.3443
N-fertilizers on irrigated rice												
N-fertilizer in continuously irrigated rice (tonnes of N per year)	2,293.24	2,293.24	0.00	-	-	57,298	10,027	218,622	38,259	275,920	48,286	-227634.3735
N-fertilizer in wet and dry irrigated rice (tonnes of N per year)	0.00	0.00	1,985.87	-	-	0	68,225	0	156,189	0	224,414	224414.0842
Organic N-fertilizers												
Sewage (tonnes of N per year)	0.00	0.00	0.00	-	-	0	0	-	-	0	0	0
Compost (tonnes of N per year)	151.16	151.16	307.23	-	-	6,924	12,822	-	-	6,924	12,822	5897.979299
Rendering waste, brewery waste, guano (tonnes of N per year)	0.00	0.00	0.00	-	-	0	0	-	-	0	0	0
Pesticides												
Fungicides (tonnes of active ingredient)	0.00	0.00	0.00	-	-	-	-	0	0	0	0	0
Herbicides (tonnes of active ingredient)	0.00	0.00	0.00	-	-	-	-	0	0	0	0	0
Insecticides (tonnes of active ingredient)	0.00	0.00	0.00	-	-	-	-	0	0	0	0	0
Animal feed (in tonnes per year)												
User defined (Tier 2)	0.00	0.00	0.00							0	0	0
									Total inputs (tCO2-e)	**297,704**	**301,499**	**3795.150739**

Figure 8: Carbon balance of energy consumption

9.2. ENERGY CONSUMPTION (electricity, fuel…) except for irrigation, i.e. see next section

If country-specific data are available, please go to Tier 2: Tier 2

Description and unit to report	Quantity consumed per year			**Total emissions (tCO2-e)**		**Balance**
Electricity (MWh per year)	Start	Without	With	Without	With	
Country of origin of electricity						
Please select	0.00	0.00	0.00	0	0	0
User defined (Tier 2)	0.00	0.00	0.00	0	0	0
Liquid or gaseous (in m3 per year)						
Stationary - Gasoil /Diesel Oil	1,934.85	1,934.85	921.83	103,814	58,972	-44841.32228
Please select	0.00	0.00	0.00	0	0	0
Please select	0.00	0.00	0.00	0	0	0
Please select	0.00	0.00	0.00	0	0	0
User defined (Tier 2)	0.00	0.00	0.00	0	0	0
Solid (in tonnes of dry matter per year)						
Wood	0.00	0.00	0.00	0	0	0
Peat	0.00	0.00	0.00	0	0	0
Charcoal	0.00	0.00	0.00	0	0	0
Peat (from peatlands)	0.00	0.00	0.00	0	0	0
User defined (Tier 2)	0.00	0.00	0.00	0	0	0
			Total energy (tCO2-e)	**103,814**	**58,972**	**-44841.32228**

Infrastructure investments

Baseline infrastructure conditions were assessed through engineering surveys. Additionality considerations included both the emissions from construction activities and the long-term benefits of climate-resilient infrastructure that would not exist in the without-project scenario.

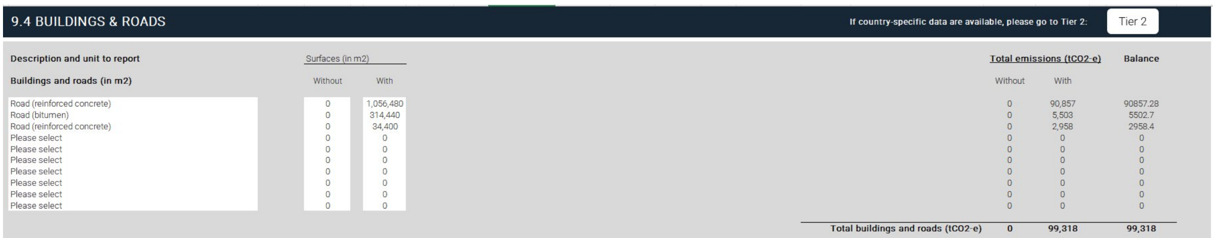
The project also invests in developing new infrastructure as follows: 113.41 km of main and secondary canals (with a bottom lining width of 4 meters for main canal; between 0.6-2.6 meter for feeder and secondary canals). Additionally, there are 1.6 kms of paved flood-protection dikes and 2.35 kms of main and secondary drains. This translates to a lining surface area of 132.07 ha and necessitates land acquisition of 23.52 ha. The project also invests in 87.21 kms of roads with 5-meter width (Table 10).

It is assumed that the construction of canal, dike, drainage and road infrastructure results in land use change from both annual fallow and flooded rice to other non-vegetated land in the EX-ACT land-use change module. For the GHG assessment, it is assumed that 80 percent of the infrastructure construction target is achieved[8]. The total carbon balance associated with construction of infrastructure is **99,318 tCO2-eq** over 20 years (Figure 9).

Table 10: Summary of infrastructure including land use changes

Infrastructure	**Start**	**Without**	**With**
Total surface lining length of canals (sqm)	0	0	1,056,480
Roads (sqm, reinforced concrete or bitumen)	0	0	348,840
OLUC (Other Landuse Changes) related to canal infrastructure	**Start**	**Without**	**With**
Annual Fallow to Other Land (non-vegetated) (Ha)	0	0	35
Flooded rice to Other Land (non-vegetated) (Ha)	0	0	24

Figure 9: Carbon balance of infrastructure



9.4 BUILDINGS & ROADS

If country-specific data are available, please go to Tier 2: Tier 2

Description and unit to report	Surfaces (in m2)		Total emissions (tCO2-e)		Balance
Buildings and roads (in m2)	Without	With	Without	With	
Road (reinforced concrete)	0	1,056,480	0	90,857	90857.28
Road (bitumen)	0	314,440	0	5,503	5502.7
Road (reinforced concrete)	0	34,400	0	2,958	2958.4
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Please select	0	0	0	0	0
Total buildings and roads (tCO2-e)			**0**	**99,318**	**99,318**

Refinement of the Analysis:
Using project specific crop yield and biomass residue yield parameters as well as number of cultivation days for different cropping systems can refine the analysis further.

References:

Ramírez Villegas, J., Rosentock, T., Steward, P., Thornton, P.K., Loboguerrero Rodriguez, A.M. and Jarvis, A., 2021. Projected climate adaptation benefits of One CGIAR. https://cgspace.cgiar.org/bitstream/handle/10568/115780/projected-adaptation-benefits-15Apr2021v2.pdf

Jiang, Y., Carrijo, D., Huang, S., Chen, J.I., Balaine, N., Zhang, W., van Groenigen, K.J. and Linquist, B., 2019. Water management to mitigate the global warming potential of rice systems: A global meta-analysis. *Field Crops Research*, *234*, pp.47-54.

[8] The IPCC currently does not provide a specific Tier 1 emission factor for canal construction. In such cases, it is considered acceptable to utilize the nearest relevant category available. In this particular instance, this aligns with road construction utilizing reinforced concrete. This approach can be viewed as a conservative one in the absence of specific data pertaining to canal construction, as it considers material similarities, and overlaps in the construction processes.