Annex 3. Economic and Financial Analysis of the project OCRI Bénin

Section 1. Climate change impact and adaptation measures regarding Ouémé agricultural production and value chains

1. Project baseline studies (2019 and February-March 2022, integrated in Annex 2) revealed climate change impact on tree and crop productivity as perceived by the local population, as well as some known adaptation measures. Table 1 summarises the findings in the study aggregated for the entire project target area.

Table 1. The climate change impact on production of staple crops, vegetables and agroforestry trees and locally proposed adaptation measures1.

	Culture		
Tree / Crop	Climate change impact	Adaptation measures	Measures expected impact
Maize (staple crops)	irregular rain affects production second season not feasible heat affects labour heavy winds (upper Ouémé) so, agrochemicals ineffective floods destroy crop (lower Ouémé) increased costs by agrochemical application	short cycle varieties drought-resistent varieties adapt planting time adapted ploughing adapted planting practice soil fertility management, fallow periods agroforestry (wind breaks; shade)	stability of yields
Vegetables	*same as for maize*	*same as for maize, plus* nursery practices culture on beds irrigation, watering, draining (construction of dams) mulching	high-quality production stability of yields counter-season production
Mango (fruits)	drought affects production heavy wind makes fruit drop	improved (grafted) varieties pruning agroforestry (risk spreading) mulching, grazing/manuring	stability of yields product quality stable wind control
Cashew (nuts)	*same as for mango*	*same as for mango* improving old plantations	*same as for mango* soil conservation
Karité (raw material)	*same as for mango*	improved varieties agroforestry (risk spreading)	*same as for mango* protection of associated culture

The studies showed that at limited scale an array of practices is used to adapt to climate change. The middle column in Table 1 represent the climate change adaptation measures that OCRI will promote through farmers' education, resulting in largely stability of yields and yield quality as shown in the right column, even in climate change scenarios. Some practices require field-level management measures (such as change of varieties, or shadow trees for labourers) and other farm or even landscape-level interventions (such as wind breaks, or water works for water conservation and irrigation); all of which OCRI will address.

The referred market studies revealed the impact of climate change on value chain management. Some climate change impact is a result of changes in agronomic conditions (e.g., the quality of produce affecting product value), others of unpredictable rain or higher temperatures (e.g., quick decay of products as a result of humidity or high temperatures).

[1] Source: Annex 19, market study : Dr. Ir. Epiphane SODJINOU, 2022. Analyse de marché et exploration des voies de mise en place d'un partenariat Agri-PPP dans la haute et la moyenne vallée de l'Ouémé. Rapport d'Étude, 113 pp. Findings are also integrated in Annex 2.

Table 2. The climate change impact on processing and sale of staple crops, vegetables and agroforestry trees and locally proposed adaptation measures.

	Processing & sales		
Tree / crop	Climate change impact	Adaptation measures	Measures expected impact
Maize (staple crops)	grains humid at harvest and deteriorate heavy rain hampers transport price hikes	drying stocking practices organised processing, transport & sale (change product) (buy from elsewhere)	stable quality capture of higher prices make up for reduced production
Vegetables	poor quality products heat affects product conservation heavy rain hampers transport price hikes	organised packaging, transport & sale	stable quality capture of higher prices make up for reduced production
Mango (fruits)	heat affects fruit conservation heavy rain hampers transport price hikes	organised packaging, transport & sale	stable quality capture of higher prices make up for reduced production
Cashew (nuts)	damaged harvest small, broken nuts humid nuts deteriorate	ventilated stockage organised processing, transport & sale	stable quality capture of higher prices make up for reduced production
Karité (raw material)	nuts humid at harvest	drying organised processing, transport & sale	stable quality capture of higher prices make up for reduced production

Similarly, OCRI is going to promote adaptation measures as presented in the Table, with expected result as in the last column.

Section 2. OCRI activities and their economic and financial rationale

Table 3 shows the activities of OCRI, and the break-down of those by funder. GCF is the prime funder of the project, followed by GOB-MAEP, GOB-MCVDD and FAO. The task division between projects funded by different donors and implementors will largely be as follows:

1. **GOB-MAEP will ensure an economic basis of climate-resilient agriculture** by supporting the realisation of agricultural value chains
2. **GCF will make agriculture investments resilient to Climate Change** by supporting the realisation of water works, climate-resilient agriculture and other adaptation measures; as well as scaling of GOB-IFAD developed resilience generating practices
3. **GOB-MCVDD will ensure the institutionalisation of climate-resilient agriculture** by arranging for maintenance of infrastructures and realising the legal conditions for cooperatives etc.
4. **FAO will lead the project and make available expertise** to ensure lessons learnt and expertise elsewhere developed are incorporated in project practice

Table 3. Expenditures of the OCRI project by component / donor, as per the OCRI budget.

Output	Total cost	Funding by GCF	Funding by GOB-MCVDD	Funding by GOB-FNEC	Funding by GOB-IFAD	Funding by FAO
Mgment cost	**$1,701,100**	$881,100	$193,800	$0	$504,000	$122,200
Component 1	**$21,375,576**	$12,135,535	$0	$0	$8,595,240	$644,801
Component 2	**$5,943,975**	$2,094,135	$336,000	$0	$3,513,840	$0
Component 3	**$6,293,925**	$3,343,025	$2,470,200	$187,500	$21,200	$272,000
Total	**$35,314,576**	**$18,453,795**	**$3,000,000**	**$187,500**	**$12,634,280**	**$1,039,001**

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5. Project investments can be attributed to proposed land cover change to realise climate-resilient agriculture. Table 4 provides an estimate on how project investments are attributed to different ‘business as usual’ land cover classes, and plus project change in land cover. The Table shows that investment levels vary greatly from $7,100/ha for irrigated land, $267/ha for restoration of degraded land, to $89/ha for Agroforestry activities, where for all acreages a ‘base’ investment of $118/ha in farmers’ training is considered.

Table 4. Project budget lines, and the direct impact on land cover change as a result of proposed activities, leading to a per-ha investment estimate.

Land Cover Change		*GCF-funded*	*GOB-IFAD funded*	*Total*	*Project investments: budget lines*	*Project investments*	*Project investments: budget / ha*
Business As Usual	*+Project*	*ha*	*ha*	*ha*		Total	
Degraded cropped dryland	Irrigated horticulture	680	1,320	**2,000**	1.1.1	$14,229,135	**$7,115**
Degraded land, riverbanks	Restored land	5,000	4,000	**9,000**	1.1.2	$2,404,140	**$267**
Degraded cropped dryland	Agroforestry	69,320	14,680	**84,000**	2.2 + 3	$7,457,925	**$89**
Total target area (ha)	(training across the project, divided over target hectares)	75,000	20,000	**95,000**	1.2 (FFS) + 2.1 (FBS) + management	$11,223,375	**$118**
Total project						**$35,314,576**	

Section 3. Agricultural Characteristics in Project Targeted Areas

6. Statistics were obtained from the Department of Agricultural Statistics (DSA) of Benin's Ministry of Agriculture, Livestock, and Fisheries (in French, MAEP). For each commune included in the project, the data include the annual number of hectares under production, annual productivity, and total production. Vegetable production with statistics includes: tomatoes, peppers, gombo (okra) and greens (grandes morelles). Staple crop production with statistics includes: maize, rice, manioc (cassava), yam, and cowpea (niebe). The dataset covers the period 1995 to 2017. A summary of agricultural statistics is presented in the worksheet "Summary ag stats". For each crop separately, details are presented in the worksheet with respective names. Key characteristics are briefly described below.

7. Total area under cultivation and total production for each crop are presented in Table 5 for vegetables and in Table 6 for staple crops. Average productivity over the period 2008-2017 as well as the yearly maximum productivity over that period of time are also presented in the same tables.

8. Over the period of observation, a total (cumulated) 382 hectares (ha) of land were devoted to the production of tomatoes in the commune of Copargo (on average 38.2 hectares per year). For the 5 communes, a total area of 16,179 ha was devoted to the production of tomatoes over the 10-year period. The commune of Glazoue alone represented approximately 50% of this total, cultivating a cumulated 8,320 ha of its land to production of tomatoes. In fact, Glazoue allocated the largest amount of land to vegetable production among all 5 communes. However, productivity (kg/ha) was higher in Copargo for tomatoes, gombo and greens, and in Djougou for peppers. Over the period 2008-2017, a yield of 17,583 kg/ha was obtained in Copargo – this maximum yield for tomatoes in Copargo was obtained in 2017. In fact, the maximum annual yield for peppers, gombo, and peppers were also observed in Copargo.

Table 5: Vegetable Production: Total Area, Total Production, and Productivity

2008-2017

	Total area (ha)	Total production (T)	Average prod (kg/ha)	Max (kg/ha)
Tomatoes				
Copargo	382	4,004	10,482	17,583
Djougou	3,547	31,925	9,001	11,617
Zagnanado	1,600	3,918	2,449	3,982
Zogbodomey	2,330	8,389	3,601	5,004
Glazoue	8,320	27,496	3,305	4,607
Total	**16,179**	**75,732**	**4,681**	
Peppers				
Copargo	520	566	1,089	5,000
Djougou	1,983	2,319	1,170	2,566
Zagnanado	1,457	1,053	723	1,425
Zogbodomey	2,298	2,126	925	2,475
Glazoue	9,009	8,866	984	1,505
Total	**15,267**	**14,931**	**978**	
Gombo (okra)				
Copargo	945	5,642	5,970	7,347
Djougou	1,515	7,624	5,032	6,500
Zagnanado	1,458	4,205	2,884	3,160
Zogbodomey	3,048	7,352	2,412	2,609
Glazoue	6,237	16,970	2,721	3,164
Total	**13,203**	**41,792**	**3,165**	
Greens (in French: grandes morelles)				
Copargo	170	652	3,834	8,700
Djougou	1,930	4,023	2,085	6,000
Zagnanado	0	-	-	0
Zogbodomey	0	-	-	0
Glazoue	0	-	-	0
Total	**2,100**	**4,675**	**2,226**	

9. With respect to annual crops, Glazoue devoted the largest amount of land for all crops except for yam. Glazoue also benefited from the largest productivity for rice and cassava. Productivity of maize and cowpea was higher in Djougou, and of yam in Copargo.

Table 6: Annual Crops: Total Area, Total Production, and Productivity

2008-2017

	Total area (ha)	Total production (T)	Average prod (kg/ha)	Max (kg/ha)
Maize				
Copargo	37,540	48,640	1,296	1,782
Djougou	89,238	155,526	1,743	2,129
Zagnanado	70,905	69,483	980	1,057
Zogbodomey	97,976	91,847	937	1,108
Glazoue	249,794	243,324	974	1,161
Total	**545,453**	**608,819**	**1,116**[2]	
Rice				
Copargo	7,620	18,919	2,483	2,800
Djougou	27,362	56,010	2,047	3,234
Zagnanado	2,144	3,677	1,715	3,500
Zogbodomey	2,190	6,333	2,892	3,693
Glazoue	51,558	187,817	3,643	5,000
Total	**90,874**	**272,756**	**3,001**	
Manioc (Cassava)				
Copargo	25,459	307,210	12,067	15,000
Djougou	20,993	271,114	12,915	18,171
Zagnanado	38,112	472,211	12,390	13,952
Zogbodomey	37,257	459,104	12,323	17,204
Glazoue	84,464	1,225,179	14,505	24,475
Total	**206,285**	**2,734,818**	**13,257**	
Yam				
Copargo	987	4,928	4,993	5,721
Djougou	1,179	5,815	4,932	5,635
Zagnanado	1,849	5,869	3,174	5,900
Zogbodomey	1,872	5,105	2,727	5,321
Glazoue	60	231	3,850	3,850
Total	**5,947**	**21,948**	**3,691**	
Cowpea (niebe)				
Copargo	9,875	7,758	786	1,030
Djougou	27,274	25,181	923	1,272
Zagnanado	26,182	19,266	736	866
Zogbodomey	38,310	27,419	716	804
Glazoue	70,123	50,044	714	789
Total	**171,764**	**129,668**	**755**	

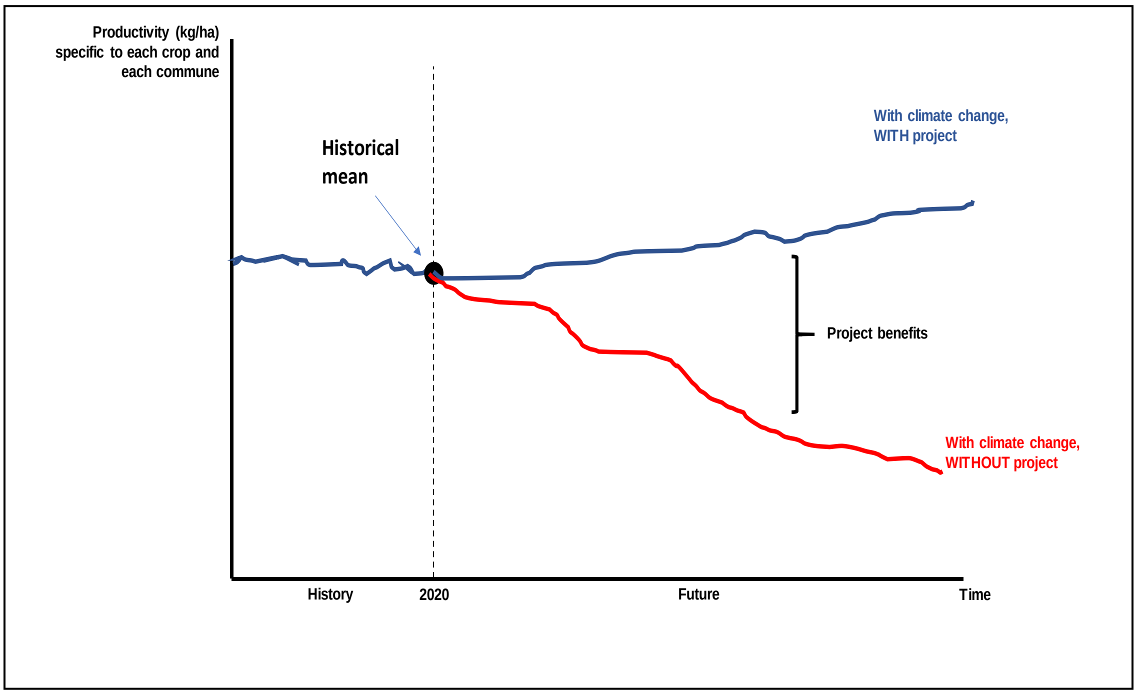
The assumption is that the interventions have direct financial benefits to the land managing actor; who are either private farmers, or landscape user groups.

[2] Akossou et al. (2016) reports average yield of maize ranging between 871 and 1,366 kg/ha. Source: Akossou, A.Y.J. et al. (2016). Spatial and temporal analysis of maize (Zea mays) crop yields in Benin from 1987 to 2007. *Agricultural and Forest Meteorology*. 220. 177-189.

Section 4. Project impact assessment approaches

10. In order to assess the potential benefits of the project, two scenarios need to be constructed (Figure 1). A first scenario pertains to assessing projected productivity (in the future) with climate change but in the absence of the project (without project scenario). A second scenario pertains to assessing projected productivity with climate change but with the project (with project scenario).

Figure 1: **Assessing the Benefits of the Project**



This document is meant to justify the foreseen project investments. Towards this end, it will deal with the comparisons of agricultural performance as presented in Table 7.

Table 7. Scenarios to-be-compared in the OCRI project economic analysis

Baseline scenario	*GCF investment scenario*	*GCF + GOB-IFAD investments scenario*	*Economic impact Calculation method*
Farm-level 1-ha baseline performance	Farm-level (1-ha) performance with climate-resilient agriculture; but limited value chain development	Farm-level (1-ha) performance with additional value chain development efforts	Plot-level performance estimate based on expected vegetation cover, farmers' capacity and access to markets[3]
Cooperative-level baseline performance (no cooperative, no climate-resilient agriculture)	Cooperative-level (10-1,000 ha) performance with climate-resilient techniques	Cooperative-level (10-1,000 ha) performance with additional value chain development efforts	Plot-level performance estimate based on expected vegetation cover, farmers' capacity and access to markets
Project-level baseline performance (with climate change)	Project-level baseline performance (with climate change adaptation)	-	Expected climate change impact on crop performance; and adaptation effects

This assessment utilises two approaches to estimate project impact, each with their own merits.

(1) **Single-crop-based projections**; that estimate project financial impact based on the improvement of single subsistence and cash crops. Calculations are presented in the accompanying excel sheet "*Economic Analysis FAO GCF OCRI Single Crop based Projections.xls"*

(2) **Multiple crop plot model-based projections**; that estimate both project financial as well as the economic impact based on a plot multiple-crop model, the FarmTree® Model[4]. Calculations are presented in the accompanying excel sheet "*Economic Analysis FAO GCF OCRI FarmTree Plot-Cooperative-Project analysis.xls*".

The FarmTree® Model – derived projections can in principle project the entire project impact. However, as for Ouémé, required data have not yet been calibrated adequately, we use the less flexible but more transparent single-crop based projections as a reference for project-level projections.

11. Given the economic importance of agriculture in the Ouémé River Basin, the potential impacts of projected climate change on agriculture have attracted the attention of both researchers and policy-makers. Using climate projections from different climate models, focusing on different subsets of crops, and using different statistical approaches and techniques, the estimated impacts of climate change vary considerably across research papers. However, consistent with the overall literature assessing the impacts of climate change on crop yields in West Africa, most research papers project a significant decrease in yields for most crops in the country. Results of the known published literature are summarized in Table 8. Overall, productivity losses range between 15 and 35% depending on the crops.

[3] Mixed cropping performance scenarios are being estimated with the FarmTree® Model, which is introduced further down in this document.

[4]

Table 8: Estimated Impacts of Climate Change on Agricultural Yield

Reports	Summary of Results
Gaiser et al. 2011[5]	In Benin: Maize yields due to projected climate change would reach up to 18% in the Upper Ouémé river basin in the period 2021–2050.
Lobell et al. 2011[6]	Across Africa: Each day spent above 30 degree Celsius reduced the final yield by 1% under optimal rain-fed conditions, and by 1.7% under drought conditions. 100% of areas will be harmed by warming under drought conditions.
Knox et al. 2012[7]	Across Africa: Average reductions in productivity by 2050 are estimated to be 17% for wheat, 5% for maize, 15% for sorghum and 10% with millet. In Benin: Specifically for Benin, yield reduction for maize is projected to be 17%, significantly higher than the estimated reduction for all of Africa.
Srivastava et al. 2012[8]	In Benin: Yam shows a reduction in average productivity ranging between 27% and 33% by 2050 under the A1B and B1 scenarios respectively.
Lawin et al. 2013[9]	In Benin: Staple crops are projected to experience substantial negative effects with a potential decline in productivity ranging between 5% to 25% for maize by 2050.
Sultan et al. 2013[10]	Across West Africa: Millet and sorghum yields are likely to decrease by up to 41% in the 21st century over West Africa because of the expected warming, irrespective of whether rainfall increases or decreases. The authors point out that t probability of a yield reduction appears to be greater in the Sudanian region, including Benin.
Ramirez-Villegas et al. 2015[11]	Across West Africa: Average productivity losses for maize is estimated to range between 10 and 20% by 2050 under RCP8.5 scenario.
Awoye et al. 2017[12]	In Benin: Pineapple, maize, groundnuts, cassava and cowpeas will face harmful effects with an average yield reduction in the range of 11%–33% by 2050.

12. In a recent paper, Hounnou et al. (2019)[13] estimated mean reductions in productivity by 2025 and 2050 for 6 different crops in Benin. These are presented in Table 9. In general, these authors report slightly lower losses than found in previous literature. This is particularly the case for yam and maize.

Table 9: Percentage Change in Productivity in Benin

	Maize	Rice	Cowpea	Sorghum	Cassava	Yam
By 2025	-4.23%	-9.45%	-8.03%	-3.93%	-7.57%	-1.38%
By 2050	-9.50%	-20.50	-17.78%	-8.87%	-16.74%	-3.13%

Source: Hounnou et al. (2019)

13. Finally, we have also examined the *Climate Adaptation in Rural Development – Assessment Tool* (CARD) recently made available by the International Fund for Agricultural Development (IFAD). The assessment tool provides estimates of the impacts of climate change for 17 major crops in nearly all African countries, including Benin.[14] For the crops selected in this project (except for yam – which is not included in the assessment tool), CARD's estimates of the impacts of climate

[5] Gaiser, T. et al. 2011. Future productivity of fallow systems in Sub-Saharan Africa: Is the effect of demographic pressure and fallow reduction more significant than climate change? *Agricultural and Forest Meteorology*. 151.1120-1130.
[6] Lobell, D.B. 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change*. 1. 42-45.
[7] Knox, J. et al. 2012. Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters*. 7. 34032.
[8] Srivastava, A. K. et al. 2012. The impact of climate change on yam (Dioscorea alata) yield in the savanna zone of West Africa. *Agriculture, Ecosystems and Environment*. 153. 57-64.
[9] Lawin, A.E. et al. 2013. Benin. In [eds]: Jalloh, A. et al. *West African Agriculture and Climate Change: A Comprehensive Analysis*. International Food Policy Research Institute, Washington, D.C. 407p.
[10] Sultan, B. et al. 2013. Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa. *Environmental Research Letters*. 8. 14040.
[11] Ramirez-Villegas, J. and P.K. Thornton. 2015. *Climate Change Impacts on African Crop Production*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Working Paper 119. Copenhagen.
[12] Awoye, O.H.R. et al. 2017. Dynamical-statistical projections of the climate change impact on agricultural production in Benin by means of a cross-validated linear model combined with Bayesian statistics. *Agricultural and Forest Meteorology*. 234–235. 80–94.
[13] Hounnou, F. E. 2019. Influence of climate change on food crop yield in Benin Republic. *Journal of Agricultural Science*. 11. 5. 281-295.

[14] The tool is available at: https://www.ifad.org/en/web/knowledge/publication/asset/41085709

change on productivity are much lower than those presented in the published literature.[15] A key impediment preventing the use of CARD's estimates is that the time horizon included in the assessment tool covers the period 2020-2039, considerably shorter than the time horizon included in the current economic analysis (2020-2050) and also available in the published literature.

14. The possible impact of climate change on vegetable and legume productivity has been much less subjected to studies than the impacts on staple crops such as cereals. In a recent study, Scheelbeek et al. (2018) wrote: "To date, no comprehensive global analysis of the impacts of environmental change on vegetables and legumes has been reported."[16] The lack of research is particularly notable given that (1) many vegetables are known to be more vulnerable to environmental conditions such as heat stress than are staple crops, and (2) vegetables and legumes are important contributors to overall nutritional quality.

15. From their meta-analysis involving 174 papers covering the period 1975 to 2016, Scheelbeek et al. (2018) reaches the following important conclusions: (1) the environmental changes predicted to occur by mid- to end-century in water availability and ozone concentrations would reduce average yields of vegetables and legumes by 35% and 9% respectively; (2) more importantly, in hot settings such as large parts of Africa (where hot settings are defined as geographical areas with baseline temperatures higher than 20 degrees Celsius), increased air temperatures would reduce average vegetable yields by an estimated 31% (with a 95% confidence interval of -21.5% to -41.4%); and (3) while increases in CO_2 may have a positive impact on vegetable and legume yields (carbon fertilization), this positive impact level off at CO_2 concentration above a baseline higher than 400 parts per million. The researchers thus conclude that: "(…) in the absence of adaptation strategies, increasing ambient temperature in (sub)tropical areas, tropospheric ozone, water salinity, and decreasing water availability would all negatively affect vegetable and legume yields."

16. More recent research articles appear to confirm the conclusions reached by Scheelbeek et al. (2018). For example, Litskas et al. (2019) concludes that in the absence of adaptation strategies: "Seven countries are projected to lose from 30% to almost all of their area suitable for tomato production. Major losses are expected to occur in parts of Africa, South Asia, Iraq and Mexico (Figure 4). Most of the affected regions are characterised by small scale agriculture, and are therefore more prone to climate change risks."[17] Benin is presented among those countries of Africa where major losses are expected to occur.

[15] For maize, rice, cassava and cowpeas, CARD estimates productivity losses of 0.46%, 1.02%, 0.99% and 0.91% by 2025, significantly lower than losses estimated by Hounnou et al. (2019) presented in Table 9.

[16] Scheelbeek, P.F.D. et al (2018). Effect of environmental changes on vegetable and legume yields and nutritional quality. *Proceedings of the National Academy of Sciences.* 115. 26. 6804-6809.

[17] Litskas, V.D. et al. (2019). Impacts of climate change on tomato, a notorious pest and its natural enemy: small scale agriculture at higher risk. *Environmental Research Letters*. 14. https://doi.org/10.1088/1748-9326/ab3313

Figure 2: Projected Changes in Area Suitable for Tomato Cultivation

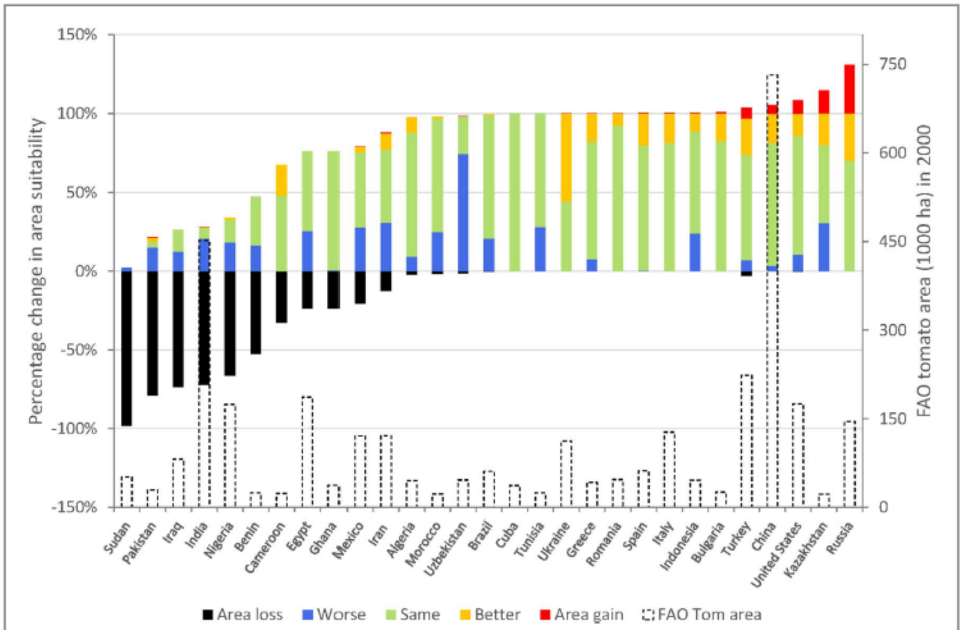


Figure 3. Change in area suitability for tomato cultivation between 1975H and 2050 (A1B—CSIRO MK.3). Data for areas equipped with AEI for 29 countries with more than 20000 ha of tomatoes in 2000 (FAOSTAT 2019), ranked from most to least affected. Area loss refers to areas suitable for tomato cultivation in 1975H (EI > 30—suitability category medium or higher) and unsuitable-low suitability (EI ⩽30) in 2050, while area gain refers to the opposite case. Worse/Better refers to a decrease/increase in area suitability, respectively. The black dashed line shows the average area of tomato cultivation (1998–2002) per country (FAOSTAT 2019).

Source: Litskas et al. (2019)

17. While not providing estimates of impacts on productivity, Abewoy et al. (2018) write: “Climate change is the primary cause of low production of most of the vegetables worldwide; reducing average yields for most of the major vegetables. Moreover, increasing temperatures, reduced irrigation-water availability, flooding, and salinity will be the major limiting factors in sustaining and increasing vegetable productivity. Under changing climatic situations crop failures, shortage of yields, reduction in quality and increasing pest and disease problems are common and they render the vegetable production unprofitable.”[18] More specifically to sub-Saharan Africa, Silva et al. (2018) writes: “Thus, large areas in sub-Saharan Africa will no longer have an optimal climate for cultivation of tomatoes. Vegetables are generally sensitive to environmental extremes and thus high temperatures and limited soil moisture are the major causes of low yields in the tropics and will be magnified by climate change.”[19] Rosegrant (2018) presents estimates of a reduction of approximately 18% in the yield of vegetables in sub-Saharan Africa by 2050.[20]

[18] Abewoy, D. et al. (2018). Review on impacts of climate change on vegetable production and its management practices. *Advances in Crop Science and Technology*. 6. 1.
[19] Silva, R.S. et al. (2017). Assessing the impact of global warming on worldwide open field tomato cultivation through CSIRO-Mk3·0 global climate model. *Journal of Agricultural Science*. 155. 407–420.
[20] Rosegrant, M.W. (2018). *Projected Impacts of Climate Change on Global Fruit and Vegetable Production through 2050*. IFPRI. A video of Rosegrant presenting the paper is available at: https://www.youtube.com/watch?v=TIz0qpbBImY

Section 5. Climate Change and Agriculture in Benin: With and Without Project

18. Over the past three decades, changes in temperature and rainfall patterns have been observed in Benin. These changes – generally adverse to the agricultural sector – include: (1) a reduction in the number of days with precipitation; (2) increased temperatures; (3) increased frequency of extreme rainfall events; and simultaneously (4) increased intensity of drought events.

19. As indicated in the Feasibility Study, agriculture is a mainstay of Benin's national economy contributing to approximately one third of Benin's gross domestic product (GDP) and providing employment to approximately two thirds of the active population.21 However, agricultural productivity continues to be heavily dependent on climate conditions as most of the cultivated land is mainly rain-fed. For maize, Akossou et al. (2016) concludes that climatic factors – in particular the quantity of rain during the periods of full vegetative growth (May in the south, and July and August in the north) - explained 15–77% of the interannual yield variations.22 This implies that agricultural productivity has already been adversely impacted by changes in climate conditions. Projected changes in temperature (with a significant increase in mean annual temperature, an increase in the number of hot days, and a decrease in the number of cold days)23 and precipitation (with an increase of the intensity of extreme weather events, including both heavy precipitation and drought)24 will continue to adversely impact Benin's agricultural sector as a whole.

20. **Production statistics** have been collected over the last decades. Crop-wise historical production data have been collected and presented in the "single crop" scenarios Excel sheet; first nine Tabs.

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[21] Ministère de l'Agriculture de l'Élevage et de la Pêche. 2017. *Plan Stratégique de Développement du Secteur Agricole 2025 et Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle 2017-2021*. Republique du Bénin.
[22] Akossou, A.Y.J. et al. 2016. Spatial and temporal analysis of maize (Zea mays) crop yields in Benin from 1987 to 2007. *Agricultural and Forest Meteorology*. 220. 177-189.
[23] McSweeney, C, et al. 2010. *UNDP Climate Change Country Profiles: Benin*. UNDP.
[24] Hounkpè, J. et al. 2016. Change in heavy rainfall characteristics over the Ouémé River Basin, Bénin Republic, West Africa. *Climate*. 4, 15.

21. In the context of the baseline case analysis, we use the estimated percentage reductions presented in Table 9. We apply these estimated reductions to staple crops presented in Table 10. As a first base case (and if and until better or more adequate information is identified), we apply a mean percentage reduction of -20% by 2050 to vegetables in light of the literature review provided in Scheelbeek et al. (2018). This percentage reduction is applied to the vegetables listed in Table 9. Hence, climate change is assumed to reduce productivity relative to the mean productivity (for each crop and each commune) experienced over the period 2008-2017. For staple crops, between the years 2020 and 2025, and then between the years 2025 and 2050, linear extrapolations are assumed to estimate projected annual productivity losses until they reach losses by 2050 values. For vegetable productivity, linear extrapolation is applied between 2020 and 2050 until productivity losses reach 20% in 2050 relative to the 2020 base year. Estimated productivity with climate change without project (*without project scenario*) is presented in Table 10 for vegetables and Table 11 for annual crops. Details are shown in the worksheet "CC Impact" of the single-crop based projections Excel file.

Table 10: Vegetable Productivity (kg/ha) with Climate Change without Project

Selected Years

	2020	2030	2040	2050
Tomatoes				
Copargo	10,482	9,783	9,085	8,386
Djougou	9,001	8,401	7,800	7,200
Zagnanado	2,449	2,285	2,122	1,959
Zogbodomey	3,601	3,361	3,120	2,880
Glazoue	3,305	3,084	2,864	2,644
Peppers				
Copargo	1,089	1,016	944	871
Djougou	1,170	1,092	1,014	936
Zagnanado	723	674	626	578
Zogbodomey	925	864	802	740
Glazoue	984	918	853	787
Gombo (okra)				
Copargo	5,970	5,572	5,174	4,776
Djougou	5,032	4,697	4,361	4,026
Zagnanado	2,884	2,692	2,499	2,307
Zogbodomey	2,412	2,251	2,090	1,930
Glazoue	2,721	2,539	2,358	2,177
Greens				
Copargo	3,834	3,578	3,323	3,067
Djougou	2,085	1,946	1,807	1,668
Zagnanado	0	-	-	-
Zogbodomey	0	-	-	-
Glazoue	0	-	-	-

Table 11: Annual Crops Productivity (kg/ha) with Climate Change without Project

Selected Years

	2020	2030	2040	2050
Maize				
Copargo	1,296	1,271	1,222	1,173
Djougou	1,743	1,710	1,643	1,577
Zagnanado	980	961	924	887
Zogbodomey	937	920	884	848
Glazoue	974	956	919	882
Cassava				
Copargo	2,483	2,483	2,483	2,483
Djougou	2,047	2,047	2,047	2,047
Zagnanado	1,715	1,715	1,715	1,715
Zogbodomey	2,892	2,892	2,892	2,892
Glazoue	3,643	3,643	3,643	3,643
Yam				
Copargo	12,067	11,663	10,855	10,047
Djougou	12,915	12,482	11,617	10,753
Zagnanado	12,390	11,975	11,146	10,316
Zogbodomey	12,323	11,910	11,085	10,260
Glazoue	14,505	14,020	13,048	12,077
Cowpea				
Copargo	4,993	4,962	4,899	4,837
Djougou	4,932	4,901	4,840	4,778
Zagnanado	3,174	3,154	3,115	3,075
Zogbodomey	2,727	2,710	2,676	2,642
Glazoue	3,850	3,826	3,778	3,729

22. Assessing the economic benefits of mitigating the projected adverse impacts of climate change on crop productivity requires a number of assumptions including the following three:

Assumption 1: It is assumed that *with the project*, productivity will come to equal the average productivity observed over the period 2008-2017, as shown in Table 10 and Table 11. This is applied to each specific crop and to each specific commune as productivity is shown to differ significantly across communes.

Assumption 2: In each commune, it is assumed that the total amount of cultivated land which will benefit from project's activities is in the same proportion as the amount of land respectively allocated to vegetable production and to staple crops over the period 2008-2017. For example, over the period 2008-2017, the commune of Copargo allocated a total of 382 ha to the production of tomatoes (see Table 9). Over the same period of time, Copargo allocated a total of 2,017 ha to the production of the 4 vegetables of interest in this project. Hence, 18.9% of the land devoted to vegetable production in Copargo was allocated to the production of tomatoes (Table 13 and 14 below present the percentage allocation of land to each crop in each commune – these are shown in the worksheet 'Summary ag stats' of the Excel file). Of the projected 7,652 ha of land which will benefit from the project's activities in Copargo, it is thus assumed that 18.9% of those hectares are hectares allocated to the production of vegetables. A similar approach is used to each crop and to each commune. In all likelihood, this assumption yields to under-estimating the true economic benefits of the project as the profit-maximizing allocation of land across crops may differ in a scenario with project from a scenario without project. It is thus implicitly assumed (most likely incorrectly) that farmers fail to identify and capture these potential incremental gains allowed by activities of the project.

Table 12: Proportion of Land Allocated of Vegetable Crops over the Period 2008-2017 (%)

	Tomatoes	Peppers	Gombo	Greens
Copargo	18.9	25.8	46.9	8.4
Djougou	39.5	22.1	16.9	21.5
Zagnanado	35.4	32.3	32.3	0.0
Zogbodomey	30.4	29.9	39.7	0.0
Glazoue	35.3	38.2	26.5	0.0

Table 13: Proportion of Land Allocated of Annual Crops over the Period 2008-2017 (%)

	Maize	Cassava	Yam	Cowpea
Copargo	46.1	31.2	1.2	12.1
Djougou	53.7	12.6	0.7	16.4
Zagnanado	50.9	27.4	1.3	18.8
Zogbodomey	55.2	21.0	1.1	21.6
Glazoue	54.8	18.5	0.0	15.4

Assumption 3: We assume that productivity gains (without vs with project scenarios) as a result of the project assumming that the number of hectares benefiting from the project's activities increases annually at the same rate as budget disbursement (e.g. if project disbursement is projected to be 35% at the end of Year 2 of project implementation, then it may be assumed that 35% of the land projected to benefit from the project activities will reach productivity levels per assumption 1); and that project impact is delayed, as it takes time to build up experience with climate-resilient farming techniques, but also to build the marketing infrastructure and link up vegetable and fruit production to marketing initiatives.

23. With these three assumptions, we compute the gain in productivity per ha in any given year relative to the "*without project*" scenario, and then compute the gain in total production in any given year relative to the same no project scenario. Results are shown in Table 14 and Table 15 for selected years.

Table 14: Estimated Impacts of the Project – Incremental Vegetable Production (kg)

Scenario: Incremental Productivity Gain through Project

	2020	2030	2040	2050
Tomatoes				
Copargo	0	92,600	104,511	116,423
Djougou	0	83,385	104,728	126,071
Zagnanado	0	37,811	43,017	48,223
Zogbodomey	0	32,118	38,675	45,233
Glazoue	0	34,585	41,586	48,587
Peppers				
Copargo	0	62,186	63,870	65,554
Djougou	0	20,063	21,613	23,164
Zagnanado	0	14,998	16,397	17,796
Zogbodomey	0	29,498	31,160	32,822
Glazoue	0	14,205	16,463	18,720
Gombo (okra)				
Copargo	0	55,488	72,271	89,053
Djougou	0	19,961	25,058	30,155
Zagnanado	0	10,939	16,526	22,114
Zogbodomey	0	10,441	16,187	21,934
Glazoue	0	11,357	15,678	19,999
Greens				
Copargo	0	26,456	28,485	30,424
Djougou	0	53,207	55,897	58,587
Zagnanado	0	-	-	-
Zogbodomey	0	-	-	-
Glazoue	0	-	-	-

Table 15: Estimated Impacts of the Project – Incremental Staple Crops Production (kg)

Scenario: Incremental Productivity Gain through Project

	2020	2030	2040	2050
Maize				
Copargo	0	127,800	134,092	140,383
Djougou	0	128,517	138,389	148,262
Zagnanado	0	32,815	38,077	43,338
Zogbodomey	0	60,707	66,157	71,608
Glazoue	0	65,290	70,914	76,539
Cassava				
Copargo	0	635,516	704,664	773,812
Djougou	0	409,058	439,003	468,948
Zagnanado	0	373,350	435,569	497,788
Zogbodomey	0	633,540	680,948	728,356
Glazoue	0	1,049,666	1,098,942	1,148,218
Yam				
Copargo	0	4,933	5,144	5,356
Djougou	0	2,798	2,921	3,043
Zagnanado	0	18,469	18,617	18,765
Zogbodomey	0	13,920	14,020	14,121
Glazoue	0	4	6	8
Cowpea				
Copargo	0	19,561	21,418	23,274
Djougou	0	36,208	39,166	42,123
Zagnanado	0	19147	21,846	24,545
Zogbodomey	0	17,226	20,236	23,247
Glazoue	0	11,269	13,410	15,550

Section 6. Project impact calculations

24. The economic impact of the project is estimated by multiplying the estimated annual gain in total production resulting from the project's activities with the estimated net revenues per production unit tonne). For each crop, monthly market prices were obtained from 6 relevant local markets over the period 2015-2016 (Table 16). For purpose of the economic analysis, an average market price was calculated and applied to estimate the economic value of the crop in 2020. This economic value is assumed constant in real terms over the period of analysis. Similarly, operation costs were estimated for each crop. These include: (1) labour cost in various parts of the cultivation process; (2) inputs such seeds and fertilizers; and (3) transport. Net economic values are reported in Table 19.

25. The above numbers and assumptions have been used to estimate the benefits of mitigating the projected impacts of climate change on agriculture in the selected 5 communes of Benin included in the proposed project. The basic Net Present Value (NPV) calculation formula used is

Project Impact NPV = NPV (Project scenario) – NPV (Baseline Scenario)

Note that there is a difference between Project *Impact* NPV and Project NPV, in which the first one is the NPV of the time-series of additional production value, and the latter also takes into account the project investments.

For the above equation, we require approximate economic values of the products to-be promoted or crops to-be-adapted to climate change. These values were collected in the project baseline mission in 2019, and are partly updated in another mission in 2022. Table 16 shows the data, aggregated from data of five communes.

Table 16. Farm Gate / Local buyer product prices assumed for the financial projection of OCRI impact on productivity[25] [26].

	2016 Gross economic value (Bulk value)	2016 Gross economic value (Bulk value)	2021 Gross economic value (Farm Gate)	2021 Gross economic value (Farm Gate)	Net/Gros value	2021 Net economic value (Farm Gate)	2021 Net economic value (Farm Gate)	Bulk value 2021	Bulk value 2021	Difference Bulk value and Farm Gate Price 2021	Bulk price change 2016 - 2021
	FCFA/Kg	USD/Kg	FCFA/Kg	USD/Kg	%	FCFA/Kg	USD/Kg	FCFA/Kg	USD/Kg	USD/Kg	%
Vegetables											
Tomatoes	403 CFA	$0.70	179 CFA	$0.31	81%	145 CFA	$0.25	272 CFA	$0.47	$0.22	-33%
Pepper	3,988 CFA	$6.94	583 CFA	$1.01	93%	543 CFA	$0.94	719 CFA	$1.25	$0.31	-82%
Gombo (okra)	352 CFA	$0.61	319 CFA	$0.55	76%	243 CFA	$0.42	386 CFA	$0.67	$0.25	10%
Greens	240 CFA	$0.42	218 CFA	$0.38	89%	193 CFA	$0.34	278 CFA	$0.48	$0.15	16%
Staple crops											
Maize	176 CFA	$0.31	194 CFA	$0.34	68%	132 CFA	$0.23	244 CFA	$0.42	$0.19	38%
Manioc	106 CFA	$0.18	68 CFA	$0.12	92%	62 CFA	$0.11	82 CFA	$0.14	$0.03	-23%
Yam	241 CFA	$0.42	550 CFA	$0.96	97%	534 CFA	$0.93	630 CFA	$1.10	$0.17	161%
Cowpea	465 CFA	$0.81	508 CFA	$0.88	85%	434 CFA	$0.75	792 CFA	$1.38	$0.62	70%
Tree products											
Mango	400 CFA	$0.70	112 CFA	$0.19	75%	84 CFA	$0.15	330 CFA	$0.57	$0.43	-18%
Cashew	1,000 CFA	$1.74	300 CFA	$0.52	75%	225 CFA	$0.39	500 CFA	$0.87	$0.48	-50%
Karité	200 CFA	$0.35	150 CFA	$0.26	75%	113 CFA	$0.20	205 CFA	$0.36	$0.16	3%
Wood	50 CFA	$0.09	50 CFA	$0.09	75%	38 CFA	$0.07	50 CFA	$0.09	$0.02	0%
Fodder	50 CFA	$0.09	50 CFA	$0.09	75%	38 CFA	$0.07	50 CFA	$0.09	$0.02	0%

2016 Source: Office National d’Appui à la Sécurité Alimentaire (ONASA); prices of 2015-2016

2021-2022 Source: Annex 19, market study : Dr. Ir. Epiphane SODJINOU, 2022. Analyse de marché et exploration des voies de mise en place d’un partenariat Agri-PPP dans la haute et la moyenne vallée de l'Ouémé. Rapport d'Étude, 113 pp.

* For wood, fodder, estimated data

[25] The office in charge of collecting market price information throughout the country (Office National d’Appui à la Sécurité Alimentaire) was dissolved in September 2016. Therefore, price data have been collected locally, without the rigidity a dedicated institution can do; yet fully based on local accounts.

[26] For the processing of locally recorded data into this Table, see accompanying Excel sheet on single-crop projections, tab “Prices and Value Chains”

26. As BAU land use and +Project land use have a value, we estimated the NPV per ha at 10% DR both for the BAU and the Project scenarios for each scenario. The NPV for vegetables and annuals is slightly higher for project than for BAU scenarios, because the gradual climate change impact that affects BAU production levels. For trees, the situation is different, as the model assumes that existing trees will stay on the land, and that newly planted trees will only start producing fruits 7 years after planting, and will be in full production 15 years after planting. For the calculations, we assumed that the project impacted vegetable production from project start. Table 17 shows the difference in NPV between the different single crop groups. The NPVs of trees are equal for each commune, as in absence of reliable data, we did not distinguish likely production per ha per commune.

Table 17. (a) Baseline (BAU) and Project Net Present Value per ha for vegetables, annuals and trees for the project target area; and (b) the weighed project impact on NPV for the target communes

(a)	BAU NPV/ha Vegetables	BAU NPV/ha Annuals	BAU NPV/ha Trees	Project NPV/ha Vegetables	Project NPV/ha Annuals	Project NPV/ha Trees
Copargo	$18,465	$5,488	$4,586	$19,495	$5,698	$7,405
Djougou	$14,834	$3,891	$4,586	$15,662	$4,020	$7,405
Glazoue	$8,565	$3,768	$4,586	$9,043	$3,921	$7,405
Zagnanado	$7,476	$4,751	$4,586	$7,893	$4,937	$7,405
Zogbodomey	$8,458	$3,880	$4,586	$8,930	$4,029	$7,405
Weighed Avg	**$9,979**	**$4,088**	**$4,586**	**$10,535**	**$4,251**	**$7,405**

(b)	BAU NPV/Ha	Project NPV/Ha	Project Impact NPV/Ha	Project Impact %
Copargo	$6,375	$7,186	$811	13%
Djougou	$5,393	$6,357	$963	18%
Glazoue	$4,687	$5,328	$641	14%
Zagnanado	$5,699	$6,254	$555	10%
Zogbodomey	$5,040	$5,660	$620	12%
Project Total	**$5,138**	**$5,825**	**$687**	**13%**

27. Besides, OCRI is promoting the development of value chains, particularly of maize, mango, cashew and karité, besides vegetables.

Sodjinou (2022)[27] , reflected in Annex 19, made an extensive analysis of the maize, karité, mango and vegetables value chains. For example, Figure 3 provides an overview of the Karité value chain in Ouémé.

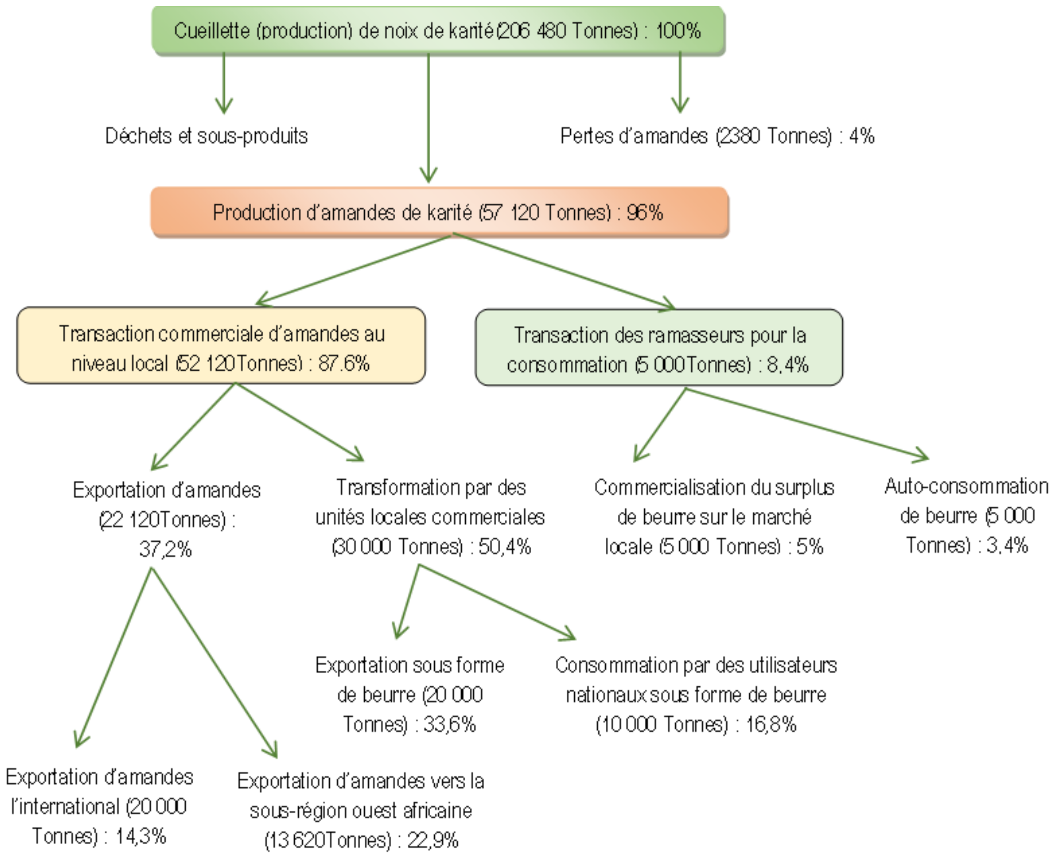

Figure 3. Overview of the value chain of Karité in the project area[28].

The financial result of promoting value chains for vegetables, maize, mango, and nuts cashew and karité have been calculated in the *single-crop based projections Excel sheet*, *Commune Summary* sheets, lines 133-136. Model settings include that 50% of the produced products are actually marketed, and that 50% of the difference between the bulk price and the farm gate price is profit. Further up in line 97-100, the resulting addition is added to the commune-level project impact over the years; where it appears in the *Indicators for Proposal* tab, line 130-134. The project-level results will be discussed further down in this document, after we discuss the project impact at plot, farm and cooperative level.

[27] Annex 19, market study : Dr. Ir. Epiphane SODJINOU, 2022. Analyse de marché et exploration des voies de mise en place d'un partenariat Agri-PPP dans la haute et la moyenne vallée de l'Ouémé. Rapport d'Étude, 113 pp.
[28] Sodjinou E. et Kouton-Bognon B. (2019). Programme National de Développement de la Filière Karité (PNDF-Karité). MAEP, Cotonou, 106p.

Section 7. Project impact calculations at plot, household and cooperative level

28. Project impact takes place on plots and in value chains of real farmers, who change their practices to become climate-resilient and plant trees to sequester carbon. Therefore we carried out provisional plot-level and cooperative level calculations; to see both the financial and economic impact of proposed changes in land use. For project economic and financial analysis, we define the baseline relative crop cover in the agriculture-covered areas. As the project is targeting rain-fed areas only, we exclude the acreages of (irrigated) rice in the different communes. To carry out projections for upper and middle Ouémé, we need to know the crop cover for both sub-regions. Table 18 shows the crop cover of the cultivated areas in upper and middle Ouémé; along with the average production by-sub-watershed, based on 2008-2017 statistics. The Table shows that the dryland crop cover does not differ significantly between upper and middle Ouémé. On the other hand, the recorded yields-per-ha are 60%-100% higher for upper Ouémé; possibly because in upper Ouémé there is only one crop cycle per year, where as in middle-Ouémé two crop cycles a year are (still) common practice; which means that – under low fertilisation practices – the two crops compete for nutrients. And, as manioc covers two seasons, this effect does not take place in manioc production.

Table 18. Crop cover and yields for main crops in upper and middle Ouémé.

	Upper Ouémé (ha cultivated)		Middle Ouémé (ha cultivated)	
	223,537		752,661	
	crop cover	average production	crop cover	average production
Maize	**56.7%**	1,610	**55.6%**	967
Manioc	20.8%	12,450	21.2%	13,492
Yam	1.0%	4,960	0.5%	2,963
Tubers total	**21.7%**		**21.7%**	
Cowpea	**16.6%**	887	**17.9%**	719
Tomatoes	1.8%	1,610	1.6%	967
Peppers	1.1%	1,153	1.7%	944
Gombo (okra)	1.1%	5,393	1.4%	2,655
Greens	0.9%	2,226	0.0%	-
Vegetables Total	**4.9%**		**4.8%**	

From: Excel sheet *Single-Crop Based Projections*, tab *Summary Agriculture Stats*.

Thus for the baseline situation both in upper and middle Ouémé, we can assume that a 1-ha farmed dryland plot is covered by the crops as indicated in Table 19. Such changes in vegetation cover, input levels and farmers' expertise (market linkage and technical capacity) are input data for the FarmTree® Model[29]; that will be used as a climate-smart agroforestry business planning tool in the project. We assumed that all tree and crop species and inputs require labour, and an impact of training on farmers' capacity and on plot performance.

The project investments are estimated from the project budget in Table 20. Farmers Field Schools cover the total target areas, and their cost is divided over all targeted 95,000 hectares. Besides, on some land, additional investments are done, such as irrigation infrastructure, land restoration; though mostly training and coordination. On all land types, training through Farmers Field Schools applies.

[29] See www. farmtree.earth . Further, see Section 52 and further for an example of a single plot projection with this tool. The estimates shown in this report are made by automatic multiple plot runs, which is a method under development by the FarmTree® Team. The tool is data-driven; while some data are presented in this report, other data are in a separate database (for an excerpt, see **Error! Reference source not found.**).

Table 19. Assumed plot cover of baseline land cover classes: degraded agriculture land, and degraded land.

Target baseline Land Cover Class	Assumed Baseline cover and practices (both in upper and middle Ouémé)
Cropped dryland *In Upper Ouémé, 1 crop cycle / year; in lower Ouémé, 2 cycles/year (except for manioc)*	Farmer characteristics: • Technical capacity: low • Marketing capacity: low Land cover: • Maize 56% • Tubers (Manioc) 21% • Cowpea 18% • Vegetables 5% Inputs level: • Fertilisation[30]: 10 kg NPK (fertiliser); 60 kg NPK [31](stray animal droppings) / ha*y
River banks and degraded land	Farmer characteristics: • Technical capacity: low • Marketing capacity: low Land cover: • Herbaceous fallow Inputs level: • Fertilisation: 60 kg NPK (stray animal droppings) / ha*y

It is important to note that **some project costs contribute indirectly to climate change resilience**, i.e., water works, where water is buffered, have a bearing on downstream communes, **which are not part of the economic analysis as yet**.

[30] See https://www.theglobaleconomy.com/Benin/fertilizer_use/; in 2008-2018 fertiliser consumption in Benin was on average around 10 kg/ha agriculture land. However, in 2019-2021 fertiliser use is increasing rapidly, and a figure of 25-50 kg/ha is probably more realistic.

[31] We assume a 'background nutrient availability' of 60 kg /ha /y; this is an estimate based on nutrient needs for expected yields under subsistence (no inorganic fertiliser) conditions.

Table 20. Provisional Estimation of project investment costs per ha, as relevant for per-ha business equation[32,33].

Land Cover Change		*GCF-funded*	*GOB-IFAD funded*	*Total*	*Project investments: budget lines*	*Project investments*	*Project investments: budget / ha*
Business As Usual	*+Project*	*ha*	*ha*	*ha*		Total	
Degraded cropped dryland	Irrigated horticulture	680	1,320	**2,000**	1.1.1	$14,229,135	**$7,115**
Degraded land, riverbanks	Restored land	5,000	4,000	**9,000**	1.1.2	$2,404,140	**$267**
Degraded cropped dryland	Agroforestry	69,320	14,680	**84,000**	2.2 + 3	$7,457,925	**$89**
Total target area (ha)	(training across the project, divided over target hectares)	75,000	20,000	**95,000**	1.2 (FFS) + 2.1 (FBS) + management	$11,223,375	**$118**
Total project						**$35,314,576**	

We can conclude that the project invests the following amounts:

- To realise irrigated land: $7,100/ha (irrigation infrastructure) + $118 (Farmer Field School)
- To restore degraded land and river banks: $339/ha (land restoration) + $118 (Farmer Field School)
- To restore degraded crop land and realise Agroforestry: $89/ha, + $118/ha (Farmer Field School)

The per-ha calculations thus do take project investments into account. For farmers therefore the financial analysis will look somewhat better, as project costs are largely subsidies.
The analysis can be done for both upper and middle Ouémé, but with now available data, the impact estimates would not differ vastly; so we base the calculations on the scenarios generated for upper-Ouémé only, and extrapolate these over the entire target area.
Further, for now, the business model calculations have been done with a repeated 2008-2017 climate data. Section 17 and further provides an economic and financial analysis taking into account climate change, based on the foreseen impact of climate change on single crops. The impact of climate change on business, and the adaptation impact of project activities, needs an elaboration and calibration of the used FarmTree® Model that is beyond the scope of this study.

29. For NPV calculations, we obviously need to assume a **discount rate**. The discount rate *subsistence farmers* implicitly assume is high; to the tune of 30%-50%; as some of them live from hand to mouth. Subsistence farmers therefore rarely invest for the long-term, and investments that break even after over a year are valued considerably less than investments that yield in the same season. On the other hand, Benin is a member of the Economic and Monetary Community of West Africa (UEMOA). In UEMOA, interest rates decisions are taken by the Central Bank of West African States' Monetary Policy Committee. The Central Bank of West African States' official rate is the key interest rate for loans to the private sector. In 2011-2021, the official

[32] Due to regular budget updates, figures used in the model may differ a few percent from the here presented numbers; however changes fall well within the margins of error
[33] As some of the marketing costs are not yet taken into account, IRRs become unrealistically high, so we gave a maximum of 50%. Field-based data will provide more accurate costs for future calculations.

interest rate for Bénin varied from 3.5% to 4.5%. Financial institutions thus must work with higher interest rates, IMF (2016) reports that there is a mandatory interest ceiling of 24%, that however, is not always observed[34]. For the NPV calculations, we therefore worked with an interest rate of 10% (which is also pretty much a standard in agriculture financial calculations).

Thus, for the different actors, we can assume a Discount Rate of:

- **4% for Government actors**
- **10% for Project Investments**
- **24% for Micro Credit loans**
- **>30% for farmers**

30. The project anticipates impact through the **following Theory of Change** (from the Funding Proposal): "*The proposed Ouémé Basin Climate-Resilience Initiative (OCRI) project aims to scale up climate resilient agriculture and low emission agroforestry practices*" through:

(1) Enhancing water management and stabilise agriculture production ("build waterworks to reduce soil erosion and run-off, and overall improve land and water management in 95,000 ha" through water works and agroforestry)

(2) Develop farmers' capacity for climate-resilient production for socio-economic and ecologic impact ("enhancing climate-resilient (…) crops with major socio-economic and/or ecologic impacts (maize, cashew, shea, mango)").

(3) Developing access to finance and marketing ("It will unlock access to finance for climate-resilient land management and agriculture.")

To quantify the economic impact of the project, we constructed the following scenarios:

(0) In the **Baseline scenario**, cropped dryland, riverbanks will continue to degrade, water will not be retained in the target area, crop yields will decline (Feasibility Study,) and downstream floods will remain occurring (Feasibility Study, Table 6).

(1) GCF investments are among others in soft and hard water management infrastructure such as water works irrigation enabling **for horticulture, agroforestry, tree cover increase for river bank stabilisation**. This step in the intervention logic is modelled as a change in land vegetation in the project impact model

(2) GCF investments are also in Farmers Field Schools to **develop farmers' capacity** for climate-resilient agriculture (horticulture, agroforestry) which leads to **higher production**[35]

[34] https://www.imf.org/external/pubs/ft/scr/2016/cr1607.pdf , p. 18
[35] For an example of such impact, see https://www.ifad.org/documents/38714182/39731420/benin_rtdpce.pdf/60cf1699-94f4-483b-bfb6-

(3) Both GCF and IFAD investments are in Farmers Business Schools and access to finance to develop farmers' value chain and marketing capacity, which leads to **higher value of farm produce**[36]. The situation here is that largely subsistence farmers use production for home consumption. With-project farmers start producing horticulture products and fruits for marketing. In the accompanying Excel file "*Economic Analysis FarmTree Plot-Farm Cooperative Economic Analysis*" the tab "*FarmTree Model Assumptions*" shows how for selected tree and crops, the assumed value changes under different marketing conditions. Subsistence crops (such as maize and beans) remain having the same value (with or without marketing capacity); while typical cash crops (vegetables, nuts) have a value that considerably reduces under poor marketing conditions, indicated through a 1-100% 'tolerance to poor marketing' variable.

In the financial project analysis, we distinguished between the above (in practice intertwined) project outputs; also to be roughly able to attribute the GCF investments to impact (separate from the IFAD and GoB contribution).

The **quantitative definitions of Trees and Crops** as used in the FarmTree® Tool are stored in a separate database, and are shown in the ". The values of biomass production, sensitivity to stresses etc. are partly based on literature data, partly on evidence from the field. The here assumed data are not all Bénin-specific and would need verification in the field, as is foreseen in the project. The here presented values are placeholder values that help estimate project impact.
In the next Sections, the four "baseline => project" scenarios are separately modelled.

31. Financial impact is calculated for **Activity 1.1.1 Build water harvesting and retention infrastructure**; with the objective to realise 2,000 ha of irrigated land (with direct beneficiaries), and reducing the peak water off flow (protecting 6 million downstream indirect beneficiaries).

This activity takes place on (baseline) degraded cropped dryland (Table 19). Activities that take place are (1) preparing a horticulture area (irrigation infrastructure) (2) technical capacity building (in FFS), and (3) marketing capacity building (in FBS). These interventions loosely represent (1) and (2) OCRI-GCF investments, and (3) GOB-IFAD investments.

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ec67a7de3c28?t=1516933368000 Section III: "The programme speeded up the popularization of improved cassava varieties and more intensive cropping techniques for roots and tubers, mainly among farmers who grow them for sale and have the necessary inputs. This helped to raise yields by 30 per cent for cassava (against the 75 per cent anticipated) and 26 per cent for yams (against the 50 per cent anticipated) in the intervention villages."

[36] For an example of impact of a micro credit and marketing project in Bénin, see https://www.ifad.org/documents/38714182/39731420/benin.pdf/aec3362c-e7a9-42f1-96cf-b5661b0a905d?t=1516933150000 , Section III.

Table 21. Cropped dryland conversion to irrigated horticulture land: assumed crop cover of Baseline and Project Interventions, that serves as an input into the FarmTree® Model for financial and economic plot-level impact calculations.

Intervention	After-project cover
Agronomic Intervention	Farmer characteristics: • Technical capacity: low • Marketing capacity: low Land cover: • Baseline: **crops are removed** • Horticulture: **Tomato (35%), Chilli peppers (29%), Okra (26%), green leaves (10%) 2 cycles / year** Inputs level: • Fertilisation: **200 kg NPK (fertiliser)**; **180 kg NPK (manure)** / **ha /y** • **Land preparation & irrigation infrastructure ($7400/ha + $740/ha /y)**
+Technical capacity development	Farmer characteristics: • Technical capacity: **high;** Marketing capacity: low Land cover: • See up Inputs level: • See up + $100/ha Farmers Field School[37]
+Marketing capacity development	Farmer characteristics: • Technical capacity: high; Marketing capacity: **high** Land cover: • See up Inputs level: • See up **+ $100/ha Farmers Business School**

[37] As budget lines get adapted during project formulations, the here assumed values might slightly differ from the finally proposed values.

With the above plot plans, we ran the FarmTree® model, and generated performance of (among others) financial indicators on a 1-ha basis. We further assumed a learning effect, so that project impact realises gradually (during project implementation, plus a 4-year period for marketing infrastructure development). Project potential impact thus increases linearly from 0% in Y-00 up to 100% in Y-10. Table 22 shows some financial results of this simulation.

Table 22. The impact on baseline of activities agronomic, +technical capacity, + marketing capacity building (for the degraded cropland => irrigated horticulture transition) for a 1-ha plot; the first 12 (of 40 simulated) years are shown. Discount Rate is assumed 10%.

Project Impact on Baseline (Financial Balance)	Average	NPV	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	$0	-$44	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cleared Cropland + irrigated horticulture crops	-$2,703	-$34,176	-$10,715	-$3,390	-$3,264	-$3,050	-$2,672	-$2,986	-$2,555	-$2,495	-$2,392	-$2,364	-$2,709	-$2,351	-$2,357
Cleared Cropland + irrigated horticulture + technical capacity development	-$941	-$29,516	-$18,811	-$8,604	-$7,906	-$5,668	-$2,532	-$2,237	-$1,636	-$467	-$84	$689	$256	$252	-$128
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	$11,292	$73,601	-$18,989	-$5,259	-$4,064	$887	$7,450	$8,739	$9,695	$12,368	$12,890	$14,554	$14,052	$13,513	$12,505
Financial balance	**Average**	**NPV**	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**	**Y10**	**Y11**	**Y12**
Cropped dryland (upper-Ouémé) Baseline	$106	$1,176	$119	$114	$80	$96	$103	$122	$105	$173	$121	$137	$133	$113	$62
Cleared Cropland + irrigated horticulture crops	-$2,596	-$35,826	-$10,595	-$3,276	-$3,184	-$2,955	-$2,568	-$2,864	-$2,450	-$2,323	-$2,271	-$2,227	-$2,576	-$2,239	-$2,294
Cleared Cropland + irrigated horticulture + technical capacity development	-$835	-$39,177	-$18,692	-$8,490	-$7,825	-$5,572	-$2,428	-$2,115	-$1,531	-$294	$38	$826	$389	$365	-$65
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	$11,398	$63,941	-$18,870	-$5,145	-$3,984	$983	$7,554	$8,861	$9,800	$12,541	$13,012	$14,691	$14,185	$13,625	$12,568
Financial revenues All (with learning effect)	**Average**	**NPV**	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**	**Y10**	**Y11**	**Y12**
Cropped dryland (upper-Ouémé) Baseline	$1,014	$10,956	$1,024	$1,028	$973	$999	$1,007	$1,042	$1,017	$1,127	$1,041	$1,066	$1,045	$1,025	$942
Cleared Cropland + irrigated horticulture crops	$2,315	$21,843	$1,024	$1,373	$1,357	$1,649	$2,056	$2,208	$2,203	$2,496	$2,421	$2,506	$2,519	$2,411	$2,246
Cleared Cropland + irrigated horticulture + technical capacity development	$12,020	$103,786	$1,024	$4,029	$4,391	$6,848	$9,993	$10,955	$11,112	$12,749	$12,729	$13,604	$13,516	$12,870	$12,130
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	$24,261	$207,099	$1,024	$7,374	$8,232	$13,402	$19,975	$21,931	$22,444	$25,584	$25,703	$27,469	$27,313	$26,130	$24,763
Labour costs	**Average**	**NPV**	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**	**Y10**	**Y11**	**Y12**
Cropped dryland (upper-Ouémé) Baseline	-$864	-$9,312	-$861	-$870	-$849	-$860	-$860	-$876	-$868	-$911	-$876	-$886	-$869	-$869	-$836
Cleared Cropland + irrigated horticulture crops	-$3,655	-$39,241	-$3,730	-$3,624	-$3,515	-$3,579	-$3,599	-$3,708	-$3,627	-$3,794	-$3,666	-$3,708	-$3,731	-$3,625	-$3,515
Cleared Cropland + irrigated horticulture + technical capacity development	-$11,594	-$124,443	-$11,742	-$11,494	-$11,191	-$11,394	-$11,396	-$11,705	-$11,618	-$12,018	-$11,666	-$11,753	-$11,763	-$11,480	-$11,170
Cleared Cropland + irrigated horticulture + technical + marketing capacity	-$11,594	-$124,443	-$11,742	-$11,494	-$11,191	-$11,394	-$11,396	-$11,705	-$11,618	-$12,018	-$11,666	-$11,753	-$11,763	-$11,480	-$11,170
Inputs + training Financial Costs	**Average**	**NPV**	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**	**Y10**	**Y11**	**Y12**
Cropped dryland (upper-Ouémé) Baseline	-$44	-$468	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44
Cleared Cropland + irrigated horticulture crops	-$1,256	-$18,428	-$7,890	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025
Cleared Cropland + irrigated horticulture + technical capacity development	-$1,260	-$18,521	-$7,974	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	-$1,269	-$18,715	-$8,152	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025	-$1,025	-$1,025	-$1,364	-$1,025	-$1,025

Table 22 shows the aggregated results of the baseline and 3 treatments; i.e., (1) technical intervention (infrastructure and agronomic measures) only; (2) technical intervention + capacity development (+ Farmers Field Schools); (3) technical intervention + capacity development + value chain development (+ Farmer Business Schools). The impact of these three treatments on the NPV of the financial costs and benefits are presented in the different (green headed) lines (financial costs, labour costs, financial revenues, the resulting financial balance) as well as the project impact compared to baseline scenarios, up to y-12 (of the total 40 year simulated). The Table shows that the high investment in developing irrigation plots and changing to horticulture crops (first 'treatment', without technical capacity building) does not give financial benefit and is in fact loss-giving (third row); as does the technical-capacity building alone (fourth row). However with both technical and marketing capacity building, the activity breaks even after Y-04 and becomes extremely profitable after Y-08. The reason for this is that, even if farmers produce abundantly, but do not sell the produce, the technical capacity does not pay off.

Table 23 summarises Table 22 and clearly shows the synergy between GCF and IFAD's activities. By just planting horticulture crops and developing technical capacity, the investment in irrigated horticulture has a negative NPV, thus farmers do not shift to this option. With marketing support (IFAD activity as well) the NPV raises to a high level of over $40k per ha.

Table 23. Summary of the impact of irrigated horticulture on a 1-ha cropped dryland. The right-table provides a sensitivity to price and costs fluctuation analysis. Discount Rate is assumed 10% (see Section 29).

			1-ha NPV of 1 + 3 project scenarios				*NPV: Sensitivity to changed costs and revenues*			
Project impact on Cropped dryland => Horticulture	Project impact on NPV	IRR	Total	Revenues	Inputs + training	Labour	Production MINUS 20%	Production PLUS 20%	Input Costs MINUS 20%	Input Costs PLUS 20%
Cropped dryland (upper-Ouémé) Baseline	-$44	n.a.	$1,176	$10,956	-$468	-$9,312	-$1,015	$3,367	$1,270	-$686
Cleared Cropland + irrigated horticulture crops	-$34,176	n.a.	-$35,826	$21,843	-$18,428	-$39,241	-$40,194	-$31,457	-$32,140	-$43,674
Cleared Cropland + irrigated horticulture + technical capacity development	-$29,516	-5%	-$39,177	$103,786	-$18,521	-$124,443	-$59,934	-$18,420	-$35,473	-$64,066
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	$73,601	>30%	$63,941	$207,099	-$18,715	-$124,443	$22,521	$105,360	$67,684	$39,052

Table 23 also shows a provisional sensitivity analysis, with plus and minus 20% of production and input costs. The Table shows that investments are robust particularly if both technical and marketing capacity are developed. The Table also shows that the IRR of the combined technical and marketing capacity building justifies project investment:

- The IRR is considerably above the interest rate of Government or Project
- The IRR is considerably lower than the interest rate of micro credit, or for farmer behavioural change

We further did an analysis of the suitability of different financing instruments from a farmers' perspective. Table 24 shows the different performance levels of a local loan (often short-term, seasonal with high interest rates), of a micro credit institution (with a locally reasonable interest rate) and if the physical investments were done as a grant (with farmers' time investment to establish part of the structure). The minimum cash flow point (when accumulated debts and interests are lowest) is provided in comparison with the national average annual income. This analysis is done for the "+ capacity development" and the "+capacity development + marketing capacity development" scenarios respectively.

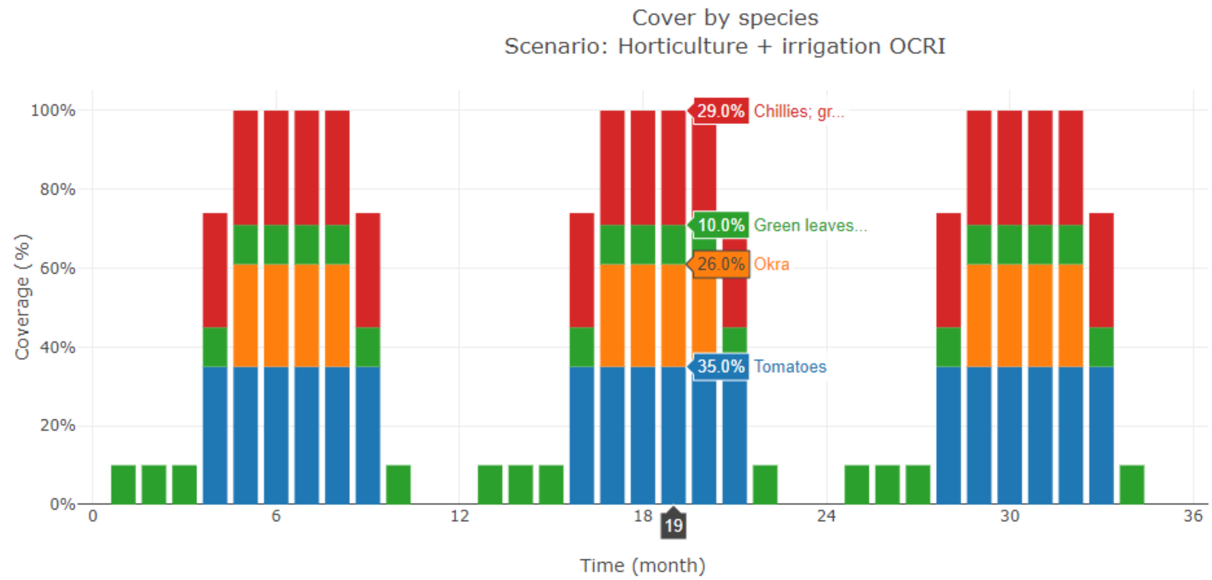
Table 24. Comparing the financial performance per capita of turning degraded land into irrigated cropland for three different financing mechanisms from a farmer's perspective.

	Per capita financial projection (farmer perspective, 9 labourers per ha)							
Cleared Cropland + irrigated horticulture + technical capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Break-Even
Cash flow farmer (local loan)	40%	< -$100,000	n.a.	-$1,286	100%	< -$10,000	>500%	never
Cash flow farmer (credit)	15%	-$54,893	n.a.	-$1,286	100%	< -$10,000	>500%	never
Cash flow farmer (grant)	0%	-$2,394	-4%	$0	0%	-$3,237	253%	never

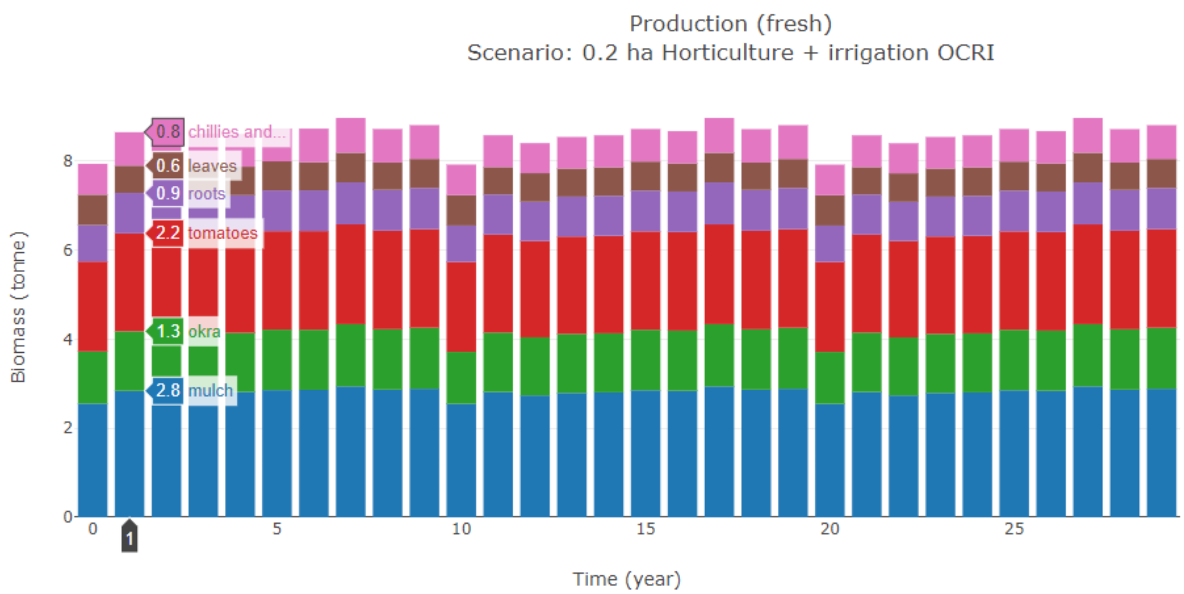
	Per capita financial projection (farmer perspective, 9 labourers per ha)							
Cleared Cropland + irrigated horticulture + technical + marketing capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Break-Even
Cash flow farmer (local loan)	40%	< -$100,000	n.a.	-$1,286	100%	< -$10,000	>500%	never
Cash flow farmer (credit)	15%	$6,135	22%	-$1,286	100%	-$3,150	246%	Y08
Cash flow farmer (grant)	0%	$9,084	54%	$0	0%	-$1,036	81%	Y05

The **farm-level business case for horticulture with irrigation** is generated with available data with the FarmTree® Tool. In this case, project investments are not taken into account, as farmers do not bear those costs, as the project provides training and some inputs. Assuming full project cover (i.e., an optimistic scenario), for a 0.2-ha plot, results are displayed in the following graphs grouped in Figure 4.

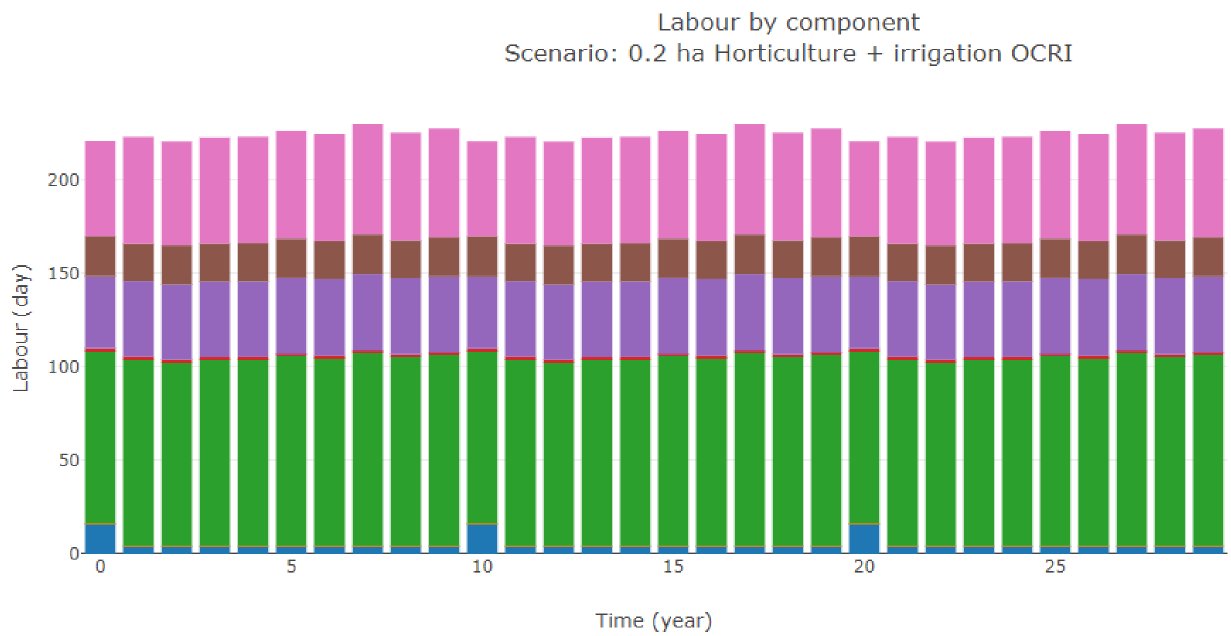
Figure 4 (a-e). Selected results of the farm-level business case for a 1-ha horticulture with irrigation, with horticulture species.



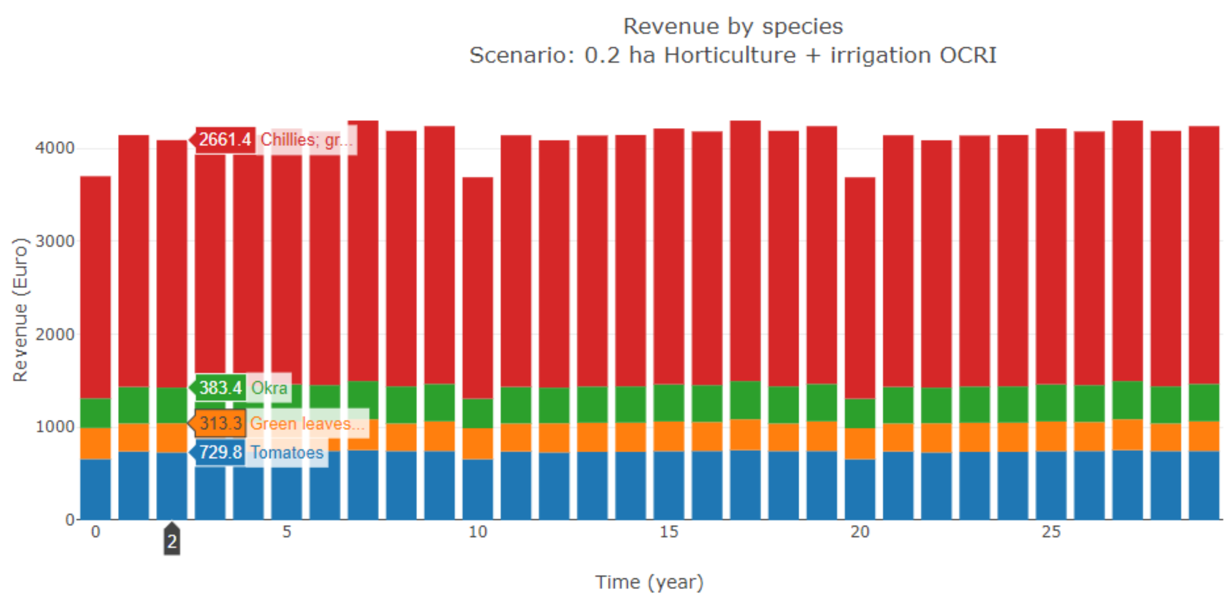
The above graph shows the crop cover in irrigated land. The model assumes that vegetables are planted two seasons in a row. In practice, the crops will be more diverse and spread more over the seasons; this however does not significantly affect the economic analysis.



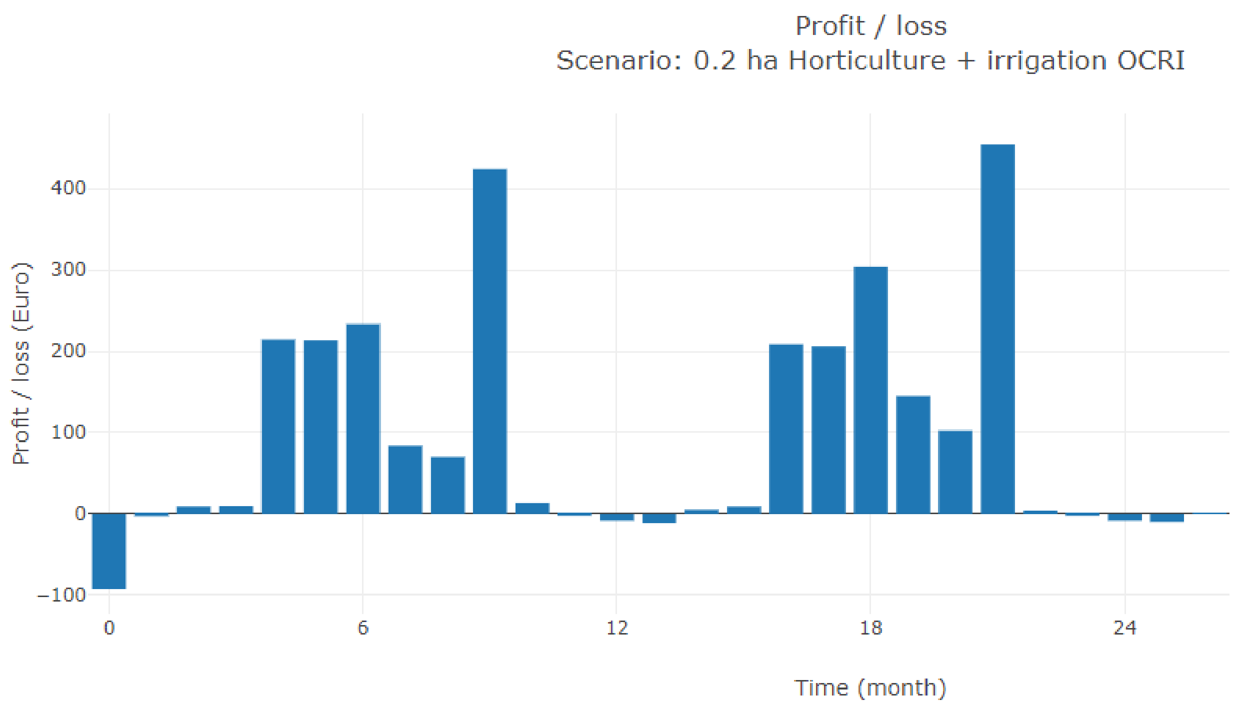
After the water works and irrigated land are established, land cover changes drastically. In practice, farmers will gradually grow their production capacity and change land cover accordingly. The model however shows how horticulture crops are introduced right-after project implementation.



Horticulture is a labour-intense activity. The model assumes that farmers invest time at training (every 10 years) and get annual updates, for example for attending cooperative meetings and the like. However, training is only a small fraction of all labour farmers invest in the system.



Under highly favourable conditions, and if produced counter-season, horticulture can be profitable. In this situation all products together amount to a total of around US$ 4,800 (€4,000) per ha per year. (The FarmTree® demo model does not have a currency exchange function as yet; this is under construction.)



From a farmers' perspective the profits and loss occur following the different seasons. In Y-0 the farmers' investment in training is indicated.

While generating this scenario, we noted that the horticulture scenario is quite sensitive to farmers' capacity, inputs, etc. In reality, a horticulture business model has to capture data from real-life experience in more detail and assess the profit and loss factors accurately for each individual farm.

32. Financial analysis is calculated for **Activity 1.1.2 Strengthen degraded river banks and restore degraded land**; with the objective to realise 9,000 ha of pasture land / orchards managed by cooperatives (direct beneficiaries) and reducing the peak water off flow (protecting 6 million downstream indirect beneficiaries).

This activity takes place on (baseline) degraded dryland (Table 19). Activities that take place are (1) planting local firewood species, Shea and Mango (2) technical capacity building (in FFS), and (3) marketing capacity building (in FBS). Table 25 shows how 'treated' plots differ from the baselines plots through the bold interventions. These interventions loosely represent (1) and (2) OCRI-GCF investments, and (3) GOB-IFAD investments.

Table 25. Degraded dryland conversion to restored degraded land: assumed crop cover of Baseline and Project Interventions, that serves as an input into the FarmTree® Model for financial and economic plot-level impact calculations.

Intervention	After-project cover
Agronomic Intervention	Farmer characteristics: • Technical capacity: low • Marketing capacity: low Land cover: • Baseline + **Shea (50%), Mango (25%), local firewood trees (25%)+ intercropped grasses etc** Inputs level: • Fertilisation: animal droppings 60 kg NPK / ha /y • **Training & seedlings provision etc $198/ha**[38]
+Technical capacity development	Farmer characteristics: • Technical capacity: **high;** Marketing capacity: low Land cover: See up Inputs level: • See up **+ $111/ha Farmers Field School**
+Marketing capacity development	Farmer characteristics: • Technical capacity: high; Marketing capacity: **high** Land cover: See up Inputs level: • See up **+ $98/ha Farmers Business School**

With the above plot plans, we ran the FarmTree® model, and generated (among others) financial performance on a 1-ha basis. We further assume a slowed learning effect, so that project impact realises gradually (during project implementation). Project impact thus increases linearly up to 100% in year-6. Table 26 shows some financial results of this simulation, which represent cash-flow projections for farm-level enterprises (to be scaled according to individual farms' land holding).

[38] As budget lines get adapted during project formulations, the here assumed values might slightly differ from the finally proposed values.

Table 26. The impact on baseline of activities agronomic, +technical capacity, + marketing capacity building (for the degraded dryland => restored dryland transition) for a 1-ha plot; the first 12 (of 40 simulated) years are shown. Discount Rate is assumed 10%.

Project Impact on Baseline (Financial	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Degraded land (upper-Ouémé) Baseline	$0	$2	$0	$0	$0	$1	$1	$1	$0	$0	$0	$0	$0	$0	$0
BL+Land Restoration ; without capacity development	-$264	-$2,283	-$272	-$112	-$153	-$235	-$173	-$192	-$211	-$372	-$199	-$180	-$181	-$426	-$186
BL+Land Restoration ; +technical capacity development	$42	-$444	-$357	-$160	-$227	-$363	-$235	-$211	-$164	-$327	-$18	$57	$140	-$128	$216
BL+Land Restoration ; +technical +marketing capacity development	$1,758	$11,185	-$535	-$149	-$189	-$261	$105	$374	$596	$698	$1,105	$1,331	$1,735	$1,792	$2,077

Financial balance	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Degraded land (upper-Ouémé)	-$90	-$968	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90
BL+Land Restoration ; without capacity development	-$354	-$3,439	-$362	-$202	-$243	-$325	-$263	-$282	-$301	-$462	-$289	-$270	-$271	-$516	-$276
BL+Land Restoration ; +technical capacity development	-$48	-$1,599	-$447	-$250	-$317	-$453	-$325	-$301	-$254	-$417	-$108	-$33	$50	-$218	$126
BL+Land Restoration ; +technical +marketing capacity development	$1,668	$10,030	-$625	-$239	-$279	-$351	$15	$284	$506	$608	$1,015	$1,241	$1,645	$1,702	$1,987

Financial revenues All (with learning effect)	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Degraded land (upper-Ouémé) Baseline	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
BL+Land Restoration ; without capacity development	$416	$2,898	$0	$11	$34	$97	$156	$203	$257	$417	$322	$343	$374	$573	$368
BL+Land Restoration ; +technical capacity development	$1,266	$8,820	$0	$16	$52	$154	$334	$511	$633	$933	$867	$964	$1,155	$1,568	$1,309
BL+Land Restoration ; +technical +marketing capacity development	$2,991	$20,643	$0	$27	$90	$257	$674	$1,096	$1,394	$1,958	$1,990	$2,238	$2,750	$3,489	$3,170

Labour costs	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Degraded land (upper-Ouémé)	-$90	-$968	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90	-$90
BL+Land Restoration ; without capacity development	-$767	-$6,250	-$277	-$213	-$277	-$422	-$419	-$485	-$558	-$879	-$612	-$613	-$644	-$1,090	-$644
BL+Land Restoration ; +technical capacity development	-$1,307	-$10,239	-$277	-$266	-$370	-$608	-$658	-$812	-$888	-$1,350	-$975	-$997	-$1,105	-$1,787	-$1,183
BL+Land Restoration ; +technical +marketing capacity development	-$1,307	-$10,239	-$277	-$266	-$370	-$608	-$658	-$812	-$888	-$1,350	-$975	-$997	-$1,105	-$1,787	-$1,183

Inputs + training Financial Costs	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Degraded land (upper-Ouémé) Baseline	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
BL+Land Restoration ; without capacity development	-$3	-$87	-$85	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
BL+Land Restoration ; +technical capacity development	-$8	-$179	-$170	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
BL+Land Restoration ; +technical +marketing capacity development	-$17	-$374	-$348	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Table 26 shows the aggregated results of the baseline and 3 treatments; i.e., (1) technical intervention (infrastructure and agronomic measures) only; (2) technical intervention + capacity development (+ Farmers Field Schools); (3) technical intervention + capacity development + value chain development (+ Farmer Business Schools). The impact of these three treatments on the NPV of the financial costs and benefits are presented in the different (green headed) lines (financial costs, labour costs, financial revenues, the resulting financial balance) as well as the project impact compared to baseline scenarios, up to y-12 (of the total 40 year simulated). The Table shows that investment in planting trees alone does not give economic benefit and is in fact loss-giving. With technical capacity building the activity breaks even after Y-12; and with marketing capacity building as well after Y-04.
Table 27 summarises Table 26 and again shows the synergy between GCF and IFAD's activities. By just restoring degraded area, the labour costs exceed revenues, and landscape restoration has a negative NPV, thus farmers do not shift to this option. With just technical support, the negative NPV is nearly neutralised; but with marketing support (IFAD's core activity) the NPV of project interventions raises to $11 thousand per ha. Please note that economic indicators, such as carbon, and externalities, such as reduced downstream floods, have not been taken into account in this equation, so the economic impact is higher than presented in this Table.

Table 27. Summary of the impact of Landscape Restoration on a 1-ha cropped dryland. The right-table provides a sensitivity to price and costs fluctuation analysis. Discount Rate is assumed 10% (see Section 29).

			1-ha NPV of 1 + 3 project scenarios				*NPV: Sensitivity to changed costs and revenues*			
Project impact on Degraded Land => Restored land	Project impact on NPV	IRR	Total	Revenues	Inputs + training	Labour	Production MINUS 20%	Production PLUS 20%	Input Costs MINUS 20%	Input Costs PLUS 20%
Degraded land (upper-Ouémé) Baseline	$2	n.a.	-$968	$0	$0	-$968	-$968	-$968	-$968	-$1,162
BL+Land Restoration ; without capacity development	-$2,283	n.a.	-$3,439	$2,898	-$87	-$6,250	-$4,018	-$2,859	-$3,421	-$4,689
BL+Land Restoration ; +technical capacity development	-$444	7%	-$1,599	$8,820	-$179	-$10,239	-$3,363	$165	-$1,563	-$3,647
BL+Land Restoration ; +technical +marketing capacity development	$11,185	>30%	$10,030	$20,643	-$374	-$10,239	$5,902	$14,159	$10,105	$7,982

Table 27 also shows a provisional sensitivity analysis, with plus and minus 20% of production and input costs. The Table shows that investments are robust if both technical and marketing capacity are developed. In the latter scenario we assume all goes well (stable technical capacity, no production losses, market prices remain stable and high) and the IRR becomes unrealistically high. In practice there are always bottlenecks that temper plot performance.

The Table also shows that the IRR of the combined technical and marketing capacity building justifies project investment:

- The IRR of the 'technical capacity development' option is above the interest rate of Government, and to the tune of the assumed Project investment rate

- The IRR of the technical + marketing capacity development scenario is higher than the interest rate of micro credit, and for farmer behavioural change. This means that it is a viable option – which farmers however can only achieve with project investments. In theory, banks could invest in this option, which would be a good follow-up of the project.

We further did an analysis of the suitability of different financing instruments from a farmers' perspective. Table 28 shows the different performance levels of a local loan (often short-term, seasonal with high interest rates), of a micro credit institution (with a locally reasonable interest rate) and if the physical investments were done as a grant (with farmers' time investment to establish part of the structure). The minimum cash flow point (when accumulated debts and interests are lowest) is provided in comparison with the national average annual income. This analysis is done for the "+ capacity development" and the "+capacity development + marketing capacity development" scenarios respectively.

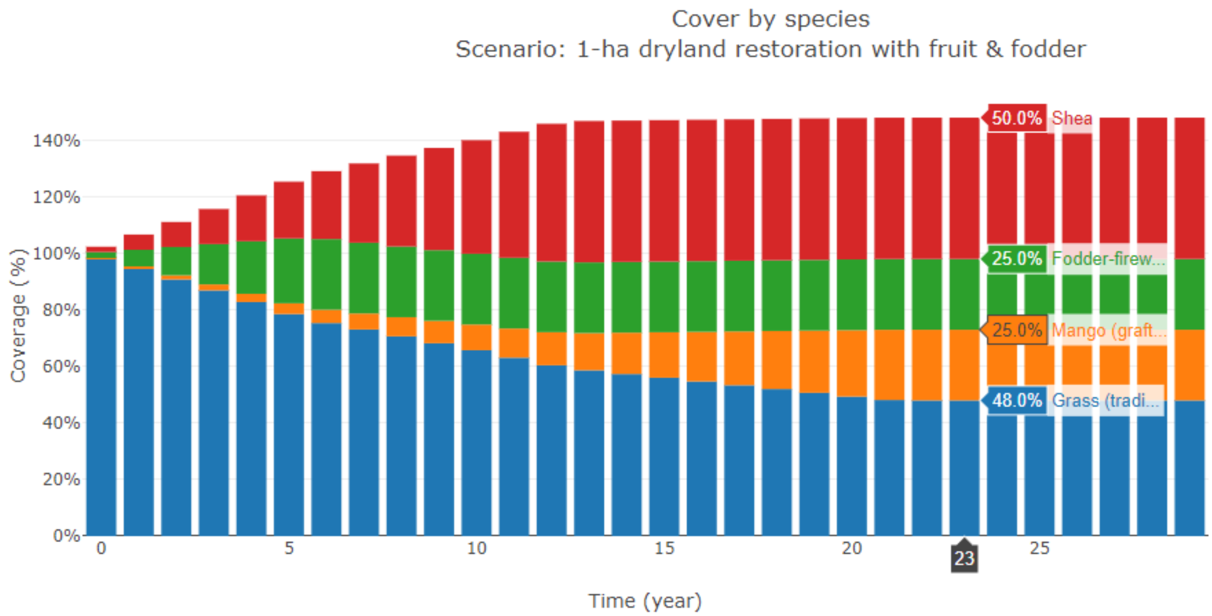
Table 28. Comparing the financial performance per capita of restoring degraded land for three different financing mechanisms from a farmer's perspective.

	Degraded Land => Restored land Per capita financial projection (farmer perspective, 3 labourers per ha)							
BL+Land Restoration ; +technical capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Year Break-Even
Cash flow farmer (local loan)	40%	< -$100,000	n.a.	-$121	9%	< -$10,000	>500%	never
Cash flow farmer (credit)	15%	-$5,065	n.a.	-$121	9%	< -$10,000	>500%	never
Cash flow farmer (grant)	0%	-$91	8%	$0	0%	-$569	44%	Y17

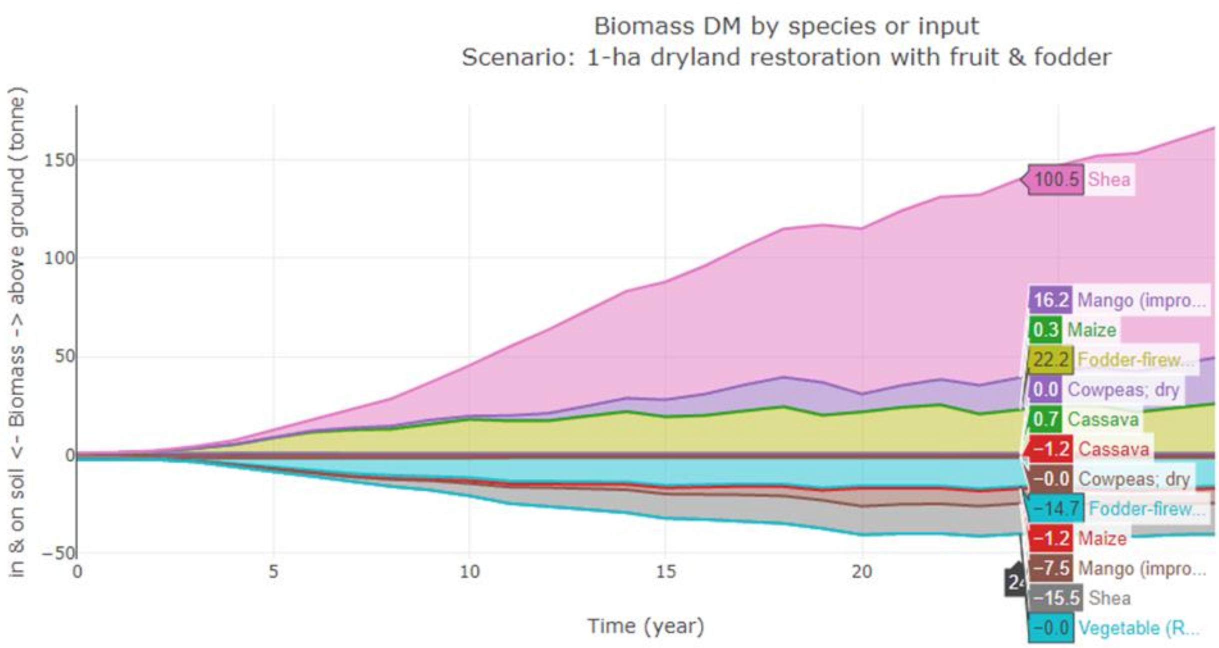
	Degraded Land => Restored land Per capita financial projection (farmer perspective, 3 labourers per ha)							
BL+Land Restoration ; +technical +marketing capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Year Break-Even
Cash flow farmer (local loan)	40%	< -$100,000	n.a.	-$121	9%	< -$10,000	>500%	never
Cash flow farmer (credit)	15%	$3,517	34%	-$121	9%	-$435	34%	Y08
Cash flow farmer (grant)	0%	$3,844	57%	$0	0%	-$200	16%	Y06

The **farm-level business case for restoring rive banks** is generated with the FarmTree® Tool. In this case, project investments are not taken into account, as training and some inputs are provided by the project. Assuming full project cover (i.e., an optimistic BL+technical+marketing capacity scenario), for a 1-ha plot, in which farmers have tenure rights and can invest and reap benefits. Results are displayed in the following graphs grouped under Figure 4.

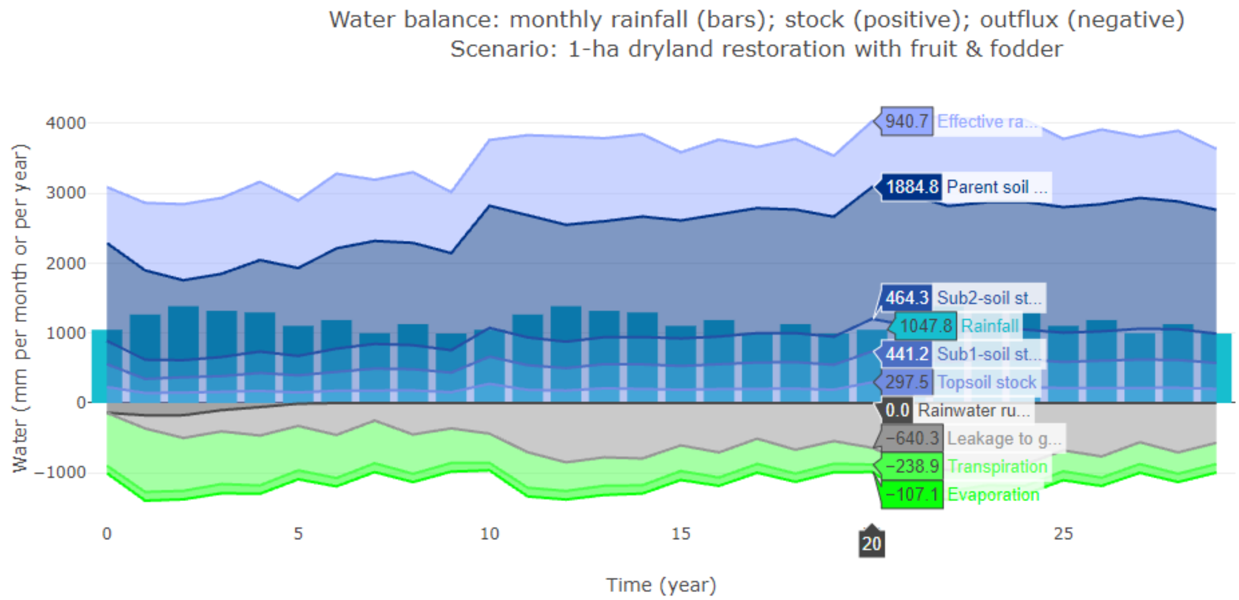
Figure 5 (a to f). Selected results of the farm-level business case for a 1-ha restoration of river banks, with fruit & fodder species.



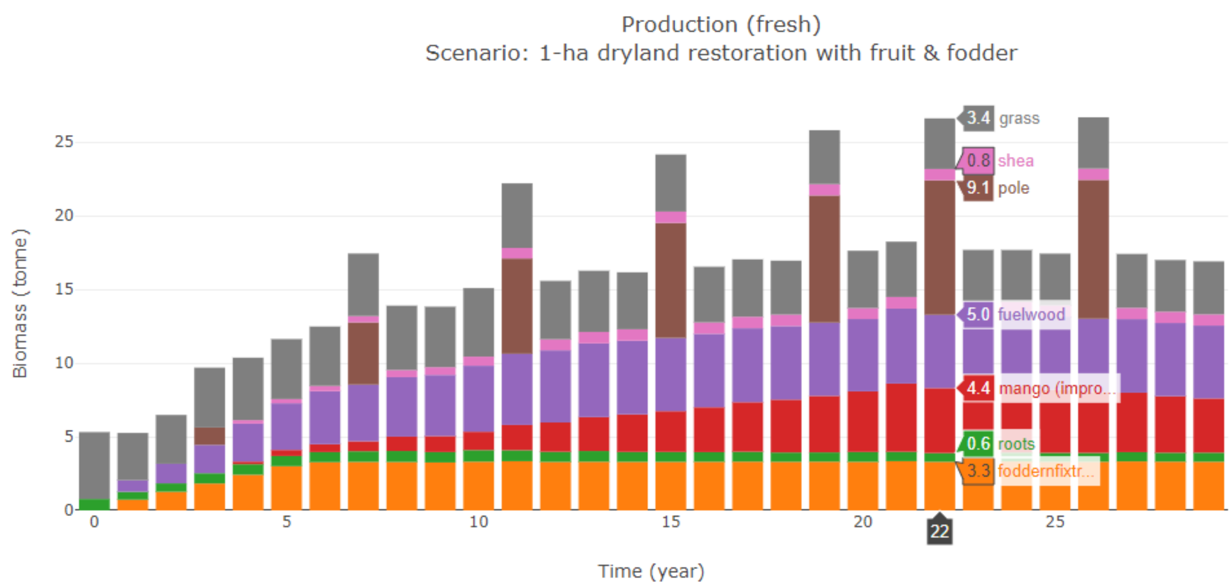
The first plot shows how – after project initiation – the plot cover changes as a result of project interventions, i.e., planting trees (orchards, shea). In the course of the years the herb cover is partly replaced by trees; and tree-crop cover increases to over 100%.



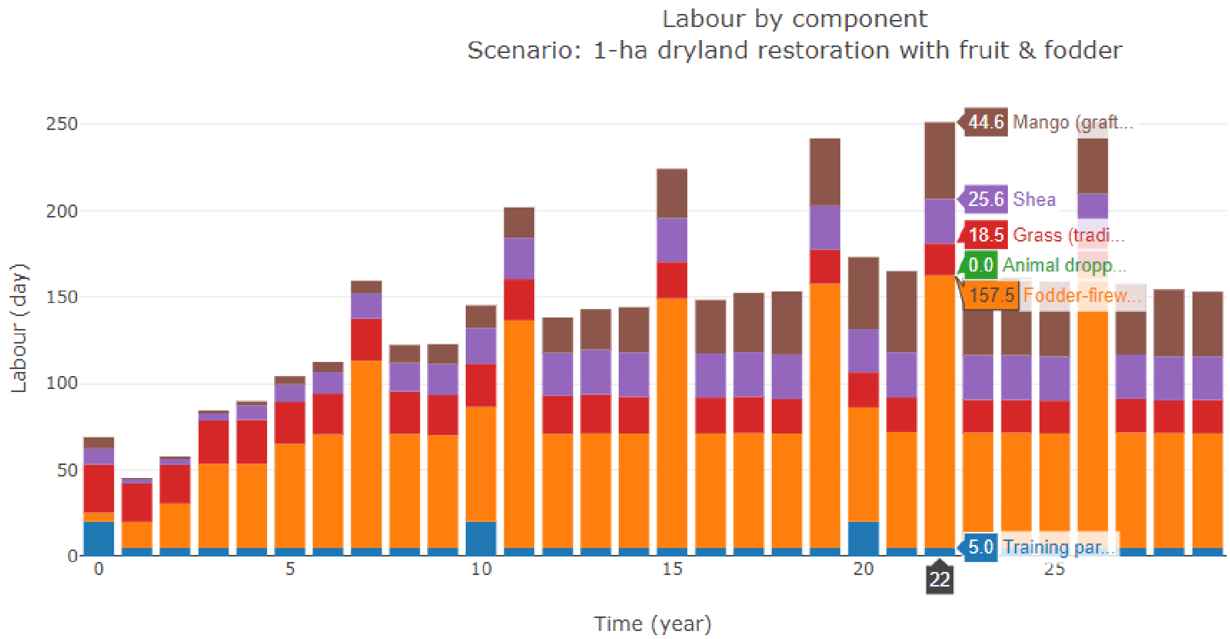
As a result of tree cover, biomass is increasing, both below and above ground. Please note that the species are yet to be calibrated, biomass of Shea seems to be overestimated.



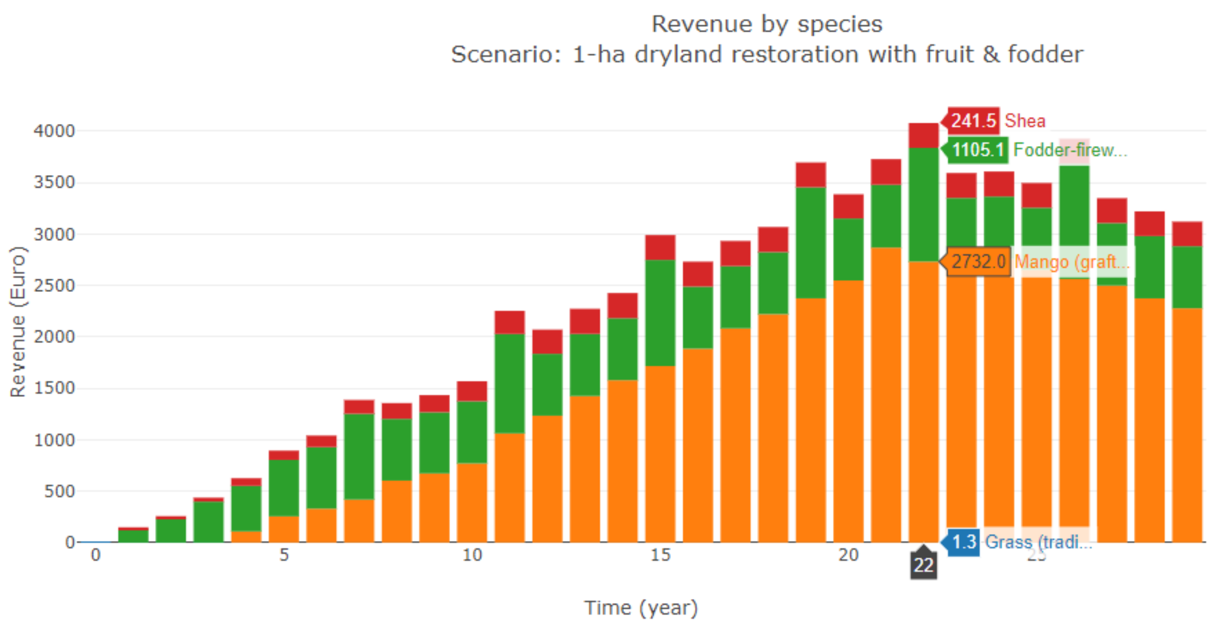
As a result of tree cover, the soil water balance stabilises. Please note that after Y-10, top soil humidity is considerably higher than initially. Also water off-flow is reduced after Y-05.



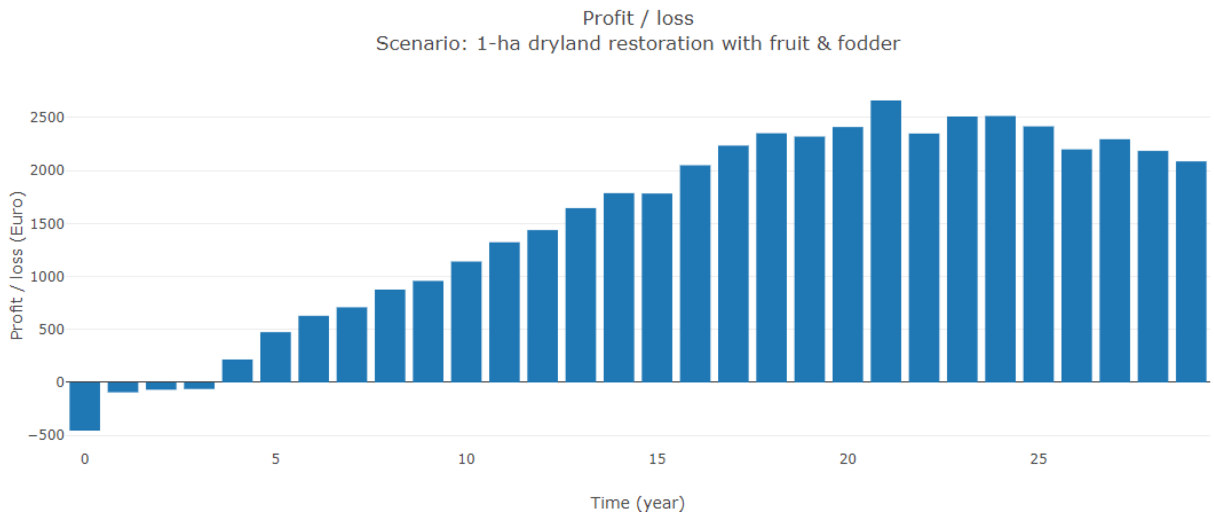
As a result of tree planting, the production of the plot diversifies from grass-only to some six additional products. In practice the number of products becomes even higher as indigenous people use local medicine, local fruits, ropes, etc.



With the increased diversity, labour input also increases; from around 40 days / ha (largely collecting local products, or fodder) to around 15 days per ha. The regular higher labour inputs occur when a certain amount of poles is harvested from the fodder-firewood trees.



Compared to the BAU-scenario, planted species produce marketable products. These are shea nuts, fodder / firewood, but mainly mango fruits. Traditional grass produces fodder, with a very low marketable value; even if (when animals graze) the resulting animal products are more valuable. The animal production is not yet accounted for in this model.



Initial costs (such as the incurred training time spent) precede profits, that start after year-4, when the planted trees will start producing. While generating this scenario, we noted that benefits are highly dependent on the production and price of fruit trees and shea nuts. Particularly fruit trees require inputs and care, which is a condition for the above profitability.

33. Financial performance is calculated for **Activity 1.2.3 Implement CRA on 95,000 ha** (which includes the 1.1.1 and 1.1.2 acreages) through training 25,250 farmers (with families) who realise climate-resilient agriculture (with direct beneficiaries) and reducing the peak water off flow (reducing climate change impact on the 6 million downstream indirect beneficiaries).

This activity takes place on (baseline) degraded cropped dryland (Table 19). Activities that take place are (1) planting high-value trees (2) technical capacity building (in FFS), and (3) marketing capacity building. These interventions loosely represent (1) and (2) OCRI-GCF investments, and (3) GOB-IFAD investments. Table 29 shows how 'treated' plots differ from the baselines plots through the **bold** interventions. These interventions loosely represent (1) and (2) OCRI-GCF investments, and (3) GOB-IFAD investments.

With the above plot plans, we ran the FarmTree® model, and generated (among others) financial performance on a 1-ha basis. Initially, agroforestry species take investments and space, without much revenues (except for some agro-ecological services). When fruit trees mature (in year-3 to 6) fruit production starts. We further assume a slowed learning effect, so that project impact from increased technical capacity realises gradually (during project implementation). Project impact thus increases linearly from zero (in the setup year) up to 100% in year-6.

Table 29. Cropped dryland conversion to agroforestry : assumed tree and crop cover of Baseline and Project Interventions, that serves as an input into the FarmTree® Model for financial and economic plot-level impact calculations.

Intervention	After-project cover
Agronomic Intervention	Farmer characteristics: • Technical capacity: low • Marketing capacity: low Land cover: • Baseline: Maize 56%; Tubers (Manioc) 21%; Cowpea 18%; Vegetables 5% • Agroforestry: **Mango (7%); Cashew (7%); Shea (7%)** Inputs level: • Fertilisation: **40 kg NPK[39] (fertiliser)**; 60 kg NPK (stray animal droppings) / ha*y
+Technical capacity development	Farmer characteristics: • Technical capacity: **high** • Marketing capacity: low Land cover: See up Inputs level: • See up + $111/ha Farmers Field School[40]
+Marketing capacity development	Farmer characteristics: • Technical capacity: high • Marketing capacity: **high** Land cover: See up Inputs level: • See up **+ $98/ha Farmers Business School**

[39] This is the 2018 value: https://www.theglobaleconomy.com/Benin/fertilizer_use/ and thus within the range of expected application of a farm with a commercial component

[40] As budget lines get adapted during project formulations, the here assumed values might slightly differ from the finally proposed values.

Table 30. The impact on baseline of activities agronomic, +technical capacity, + marketing capacity building (for the degraded cropland => agroforestry transition) for a 1-ha plot; the first 12 (of 40) years are shown. Discount Rate is assumed 10%.

Project Impact on Baseline (Financial Balance)	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	$0	-$42	$0	$0	$0	$1	$1	$1	$0	$0	$0	$0	$0	$0	$0
BL+Agroforestry ; without capacity development	$10	-$66	-$62	-$2	-$10	-$17	-$19	-$17	-$14	-$5	-$5	-$12	-$5	$1	$14
BL+Agroforestry ; +technical capacity development	$892	$6,206	-$876	-$479	-$268	-$19	$353	$483	$629	$875	$913	$1,054	$1,236	$1,265	$1,166
BL+Agroforestry ; +technical +marketing capacity	$2,424	$18,558	-$1,054	-$318	$32	$498	$1,243	$1,582	$1,881	$2,405	$2,476	$2,765	$3,106	$3,180	$2,979

Financial balance	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	$106	$1,176	$119	$114	$80	$96	$103	$122	$105	$173	$121	$137	$133	$113	$62
BL+Agroforestry ; without capacity development	$116	$1,121	$57	$112	$70	$79	$84	$106	$91	$167	$117	$125	$128	$114	$76
BL+Agroforestry ; +technical capacity development	$998	$6,673	-$757	-$365	-$188	$76	$456	$605	$734	$1,048	$1,035	$1,190	$1,369	$1,378	$1,228
BL+Agroforestry ; +technical +marketing capacity	$2,530	$19,024	-$935	-$205	$113	$594	$1,346	$1,704	$1,986	$2,578	$2,597	$2,901	$3,239	$3,292	$3,042

Financial revenues All (with learning effect)	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	$1,014	$10,956	$1,024	$1,028	$973	$999	$1,007	$1,042	$1,017	$1,127	$1,041	$1,066	$1,045	$1,025	$942
BL+Agroforestry ; without capacity development	$1,069	$11,230	$1,024	$1,021	$965	$987	$1,001	$1,042	$1,023	$1,149	$1,063	$1,078	$1,069	$1,061	$1,001
BL+Agroforestry ; +technical capacity development	$2,719	$24,894	$1,024	$1,230	$1,344	$1,641	$2,061	$2,275	$2,437	$2,883	$2,759	$2,919	$3,161	$3,141	$2,901
BL+Agroforestry ; +technical +marketing capacity	$4,260	$37,441	$1,024	$1,391	$1,644	$2,158	$2,952	$3,374	$3,689	$4,413	$4,322	$4,629	$5,031	$5,055	$4,714

Labour costs	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	-$864	-$9,312	-$861	-$870	-$849	-$860	-$860	-$876	-$868	-$911	-$876	-$886	-$869	-$869	-$836
BL+Agroforestry ; without capacity development	-$908	-$9,610	-$894	-$865	-$851	-$865	-$873	-$893	-$889	-$938	-$903	-$909	-$897	-$904	-$881
BL+Agroforestry ; +technical capacity development	-$1,665	-$17,552	-$1,615	-$1,544	-$1,480	-$1,513	-$1,553	-$1,618	-$1,651	-$1,784	-$1,673	-$1,677	-$1,742	-$1,713	-$1,623
BL+Agroforestry ; +technical +marketing capacity	-$1,665	-$17,552	-$1,615	-$1,544	-$1,480	-$1,513	-$1,553	-$1,618	-$1,651	-$1,784	-$1,673	-$1,677	-$1,742	-$1,713	-$1,623

Inputs + training Financial Costs	*Average*	*NPV*	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09	Y10	Y11	Y12
Cropped dryland (upper-Ouémé) Baseline	-$44	-$468	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44
BL+Agroforestry ; without capacity development	-$45	-$499	-$73	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44	-$44
BL+Agroforestry ; +technical capacity development	-$56	-$670	-$166	-$52	-$52	-$52	-$52	-$52	-$52	-$52	-$52	-$51	-$50	-$50	-$50
BL+Agroforestry ; +technical +marketing capacity	-$65	-$865	-$344	-$52	-$52	-$52	-$52	-$52	-$52	-$52	-$52	-$51	-$50	-$50	-$50

Table 30 shows the aggregated results of the baseline and 3 treatments; i.e., (1) technical intervention (infrastructure and agronomic measures) only; (2) technical intervention + capacity development (+ Farmers Field Schools); (3) technical intervention + capacity development + value chain development (+ Farmer Business Schools). The impact of these three treatments on the NPV of the financial costs and benefits are presented in the different (green headed) lines (financial costs, labour costs, financial revenues, the resulting financial balance) as well as the project impact compared to baseline scenarios, up to y-12 (of the total 40 year simulated). The Table shows that investment in planting trees alone breaks even after Y-10; with capacity development after Y-04, and with marketing capacity after Y-03. Table 31 summarises **Table 30** with NPVs of a one-ha plot with different project scenarios. It also provides a sensitivity analysis, varying production and cost levels. The Table shows that both technical and marketing capacity development are required to realise a financially positive project result at project level. As much of the investment costs are borne by the project (and not the farmer), for farmers the break-even will be earlier (not explicitly shown).

Table 31. Summary of the impact of Agroforestry on a 1-ha cropped dryland. The right-table provides a sensitivity to price and costs fluctuation analysis. Discount Rate is assumed 10% (see Section 29).

			1-ha NPV of 1 + 3 project scenarios				*NPV: Sensitivity to changed costs and revenues*			
Project impact on Cropped dryland => Agroforestry	Project impact on NPV	IRR	Total	Revenues	Inputs + training	Labour	Production MINUS 20%	Production PLUS 20%	Input Costs MINUS 20%	Input Costs PLUS 20%
Cropped dryland (upper-Ouémé) Baseline	-$42	n.a.	$1,176	$10,956	-$468	-$9,312	-$1,015	$3,367	$1,270	-$686
BL+Agroforestry ; without capacity development	-$66	8%	$1,121	$11,230	-$499	-$9,610	-$1,125	$3,367	$1,220	-$801
BL+Agroforestry ; +technical capacity development	$6,206	>30%	$6,673	$24,894	-$670	-$17,552	$1,694	$11,651	$6,807	$3,162
BL+Agroforestry ; +technical +marketing capacity development	$18,558	>30%	$19,024	$37,441	-$865	-$17,552	$11,536	$26,512	$19,197	$15,514

The Table also shows that the IRR of the combined technical and marketing capacity building justifies project investment:

- The IRR of the 'technical capacity development' option is above the interest rate norm of Government, and of the project.
- The IRR of the technical + marketing capacity development scenario is higher than the interest rate of micro credit, and for farmer behavioural change. This means that it is a viable option – which farmers however can only achieve with project investments. In theory, banks could invest in this option, which would be a good follow-up of the project.

We further did an analysis of the suitability of different financing instruments from a farmers' perspective. Table 32 shows the different performance levels of a local loan (often short-term, seasonal with high interest rates), of a micro credit institution (with a locally reasonable interest rate) and if the physical investments were done as a grant (with farmers' time investment to establish part of the structure). The minimum cash flow point (when accumulated debts and interests are lowest) is provided in comparison with the national average annual income. This analysis is done for the "+ capacity development" and the "+capacity development + marketing capacity development" scenarios respectively.

Table 32. Comparing the financial performance per capita of restoring degraded agriculture land into agroforestry for three different financing mechanisms from a farmer's perspective.

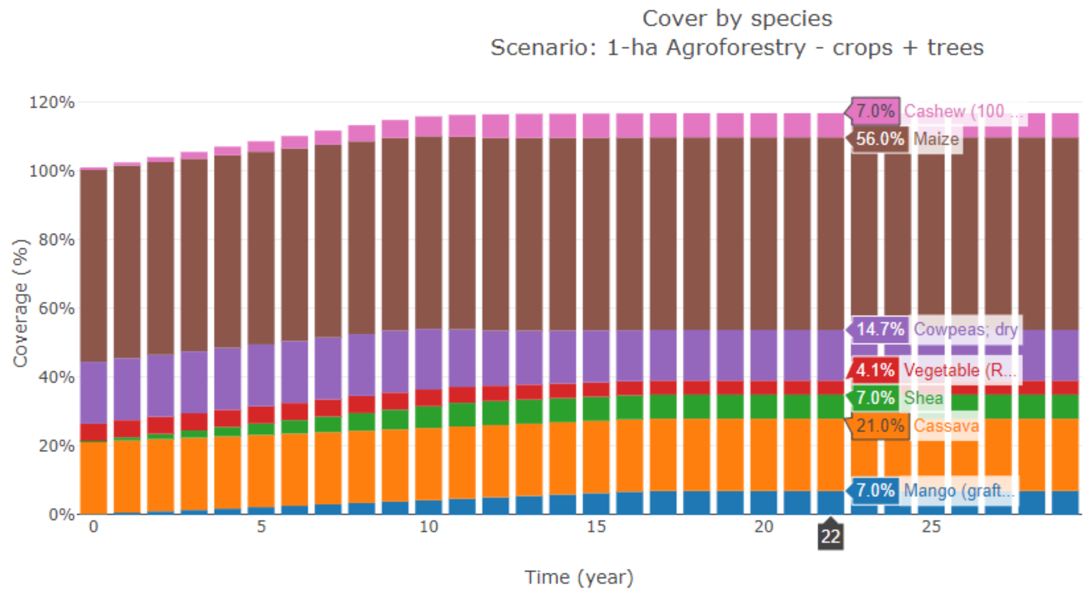
	Cropped dryland => Agroforestry Per capita financial projection (farmer perspective, 3 labourers per ha)							
BL+Agroforestry ; +technical capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Year Break-Even
Cash flow farmer (local loan)	40%	< -$100,000	n.a.	-$308	24%	< -$10,000	>500%	never
Cash flow farmer (credit)	15%	$1,320	19%	-$308	24%	-$790	62%	Y09
Cash flow farmer (grant)	0%	$2,124	45%	$0	0%	-$256	20%	Y05

	Cropped dryland => Agroforestry Per capita financial projection (farmer perspective, 3 labourers per ha)							
BL+Agroforestry ; +technical +marketing capacity development	Interest rate	NPV @10%	IRR	Investment	Investment (% of annual income)	Lowest debt	Lowest debt (% of annual income)	Year Break-Even
Cash flow farmer (local loan)	40%	$4,862	33%	-$308	24%	-$872	68%	Y07
Cash flow farmer (credit)	15%	$5,784	47%	-$308	24%	-$519	41%	Y05
Cash flow farmer (grant)	0%	$6,301	132%	$0	0%	-$106	8%	Y03

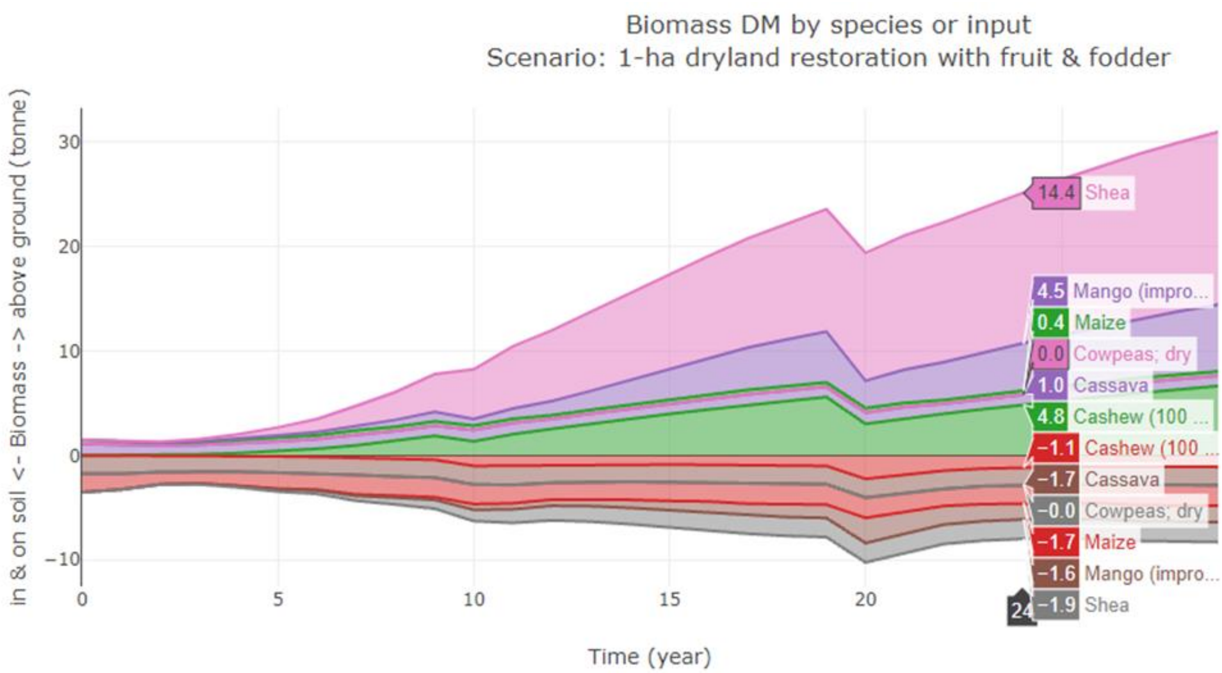
Activity 1.2.3 covers both 'restoration of degraded land' (which is simulated above) as well as 'restoration of river banks'. The latter activity is largely a climate change adaptation activity, with mainly downstream indirect beneficiaries. The managing cooperatives may get benefits in the shape of bamboo or local fodder trees, and will be in the order of magnitude of the above scenarios.

The **farm-level business case for agroforestry** is generated with the FarmTree® Tool. In this case, project investments are not taken into account, as training and some inputs are provided by the project. Assuming full project cover (i.e., an optimistic scenario), for a 1-ha plot, results are displayed in the following graphs grouped under **Figure 6**.

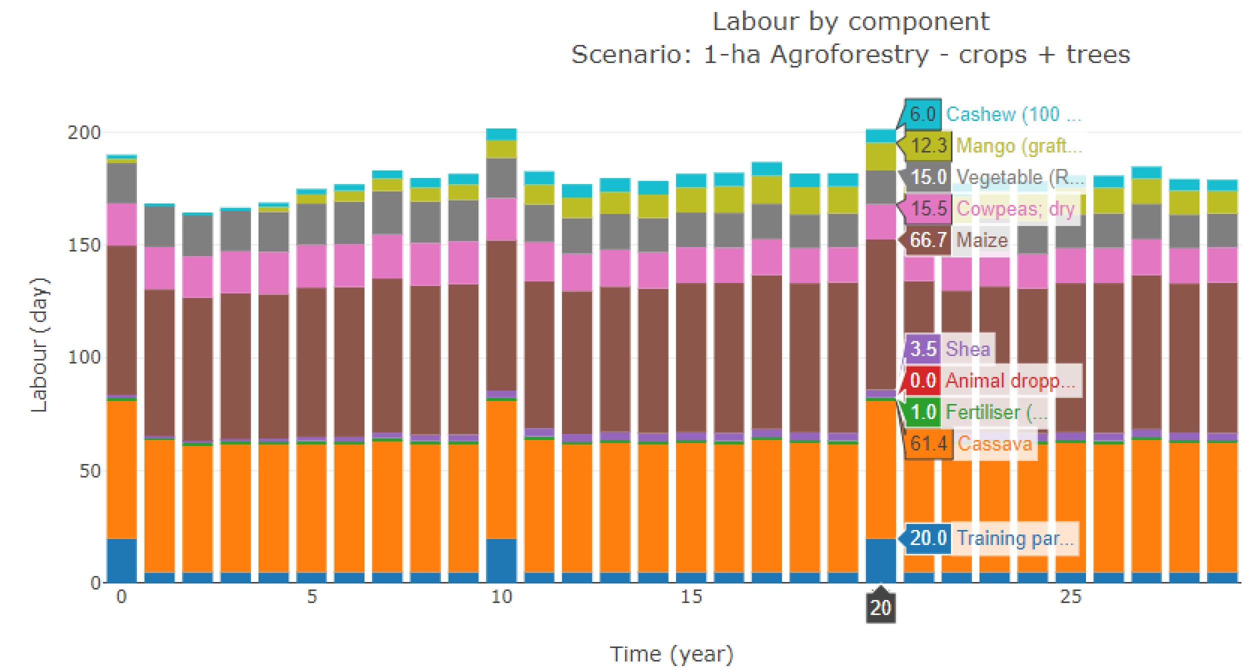
Figure 6 (a-g). Selected results of the farm-level business case for a 1-ha restoration of dryland, with fruit & fodder species.



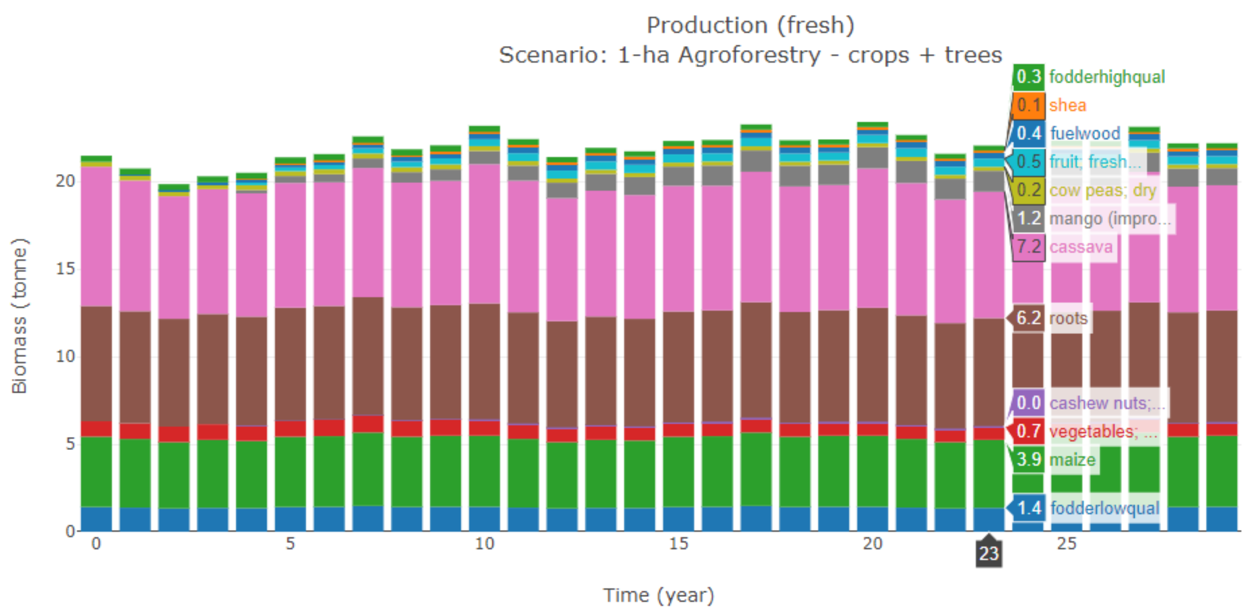
In the agroforestry scenario, fields with annual crops are enriched with tree species, for production and climate-resilience. As you can see, the tree cover increases gradually until in Y-10 or so they reach their maximum cover. The cover of annuals decreases accordingly; though a certain degree intercropping cover is assumed, and thus total cover becomes higher than 100%.



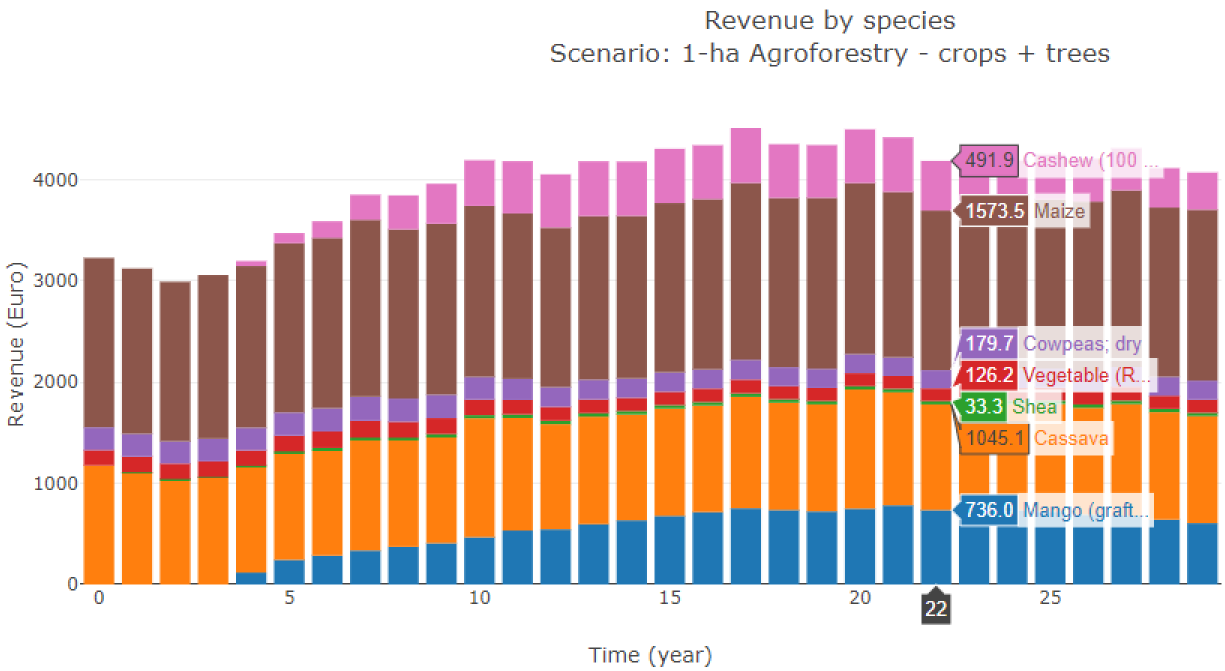
Due to increased tree cover, that gradually grows, the on-field biomass increases. The biomass growth of Shea needs calibration and is probably overestimated.



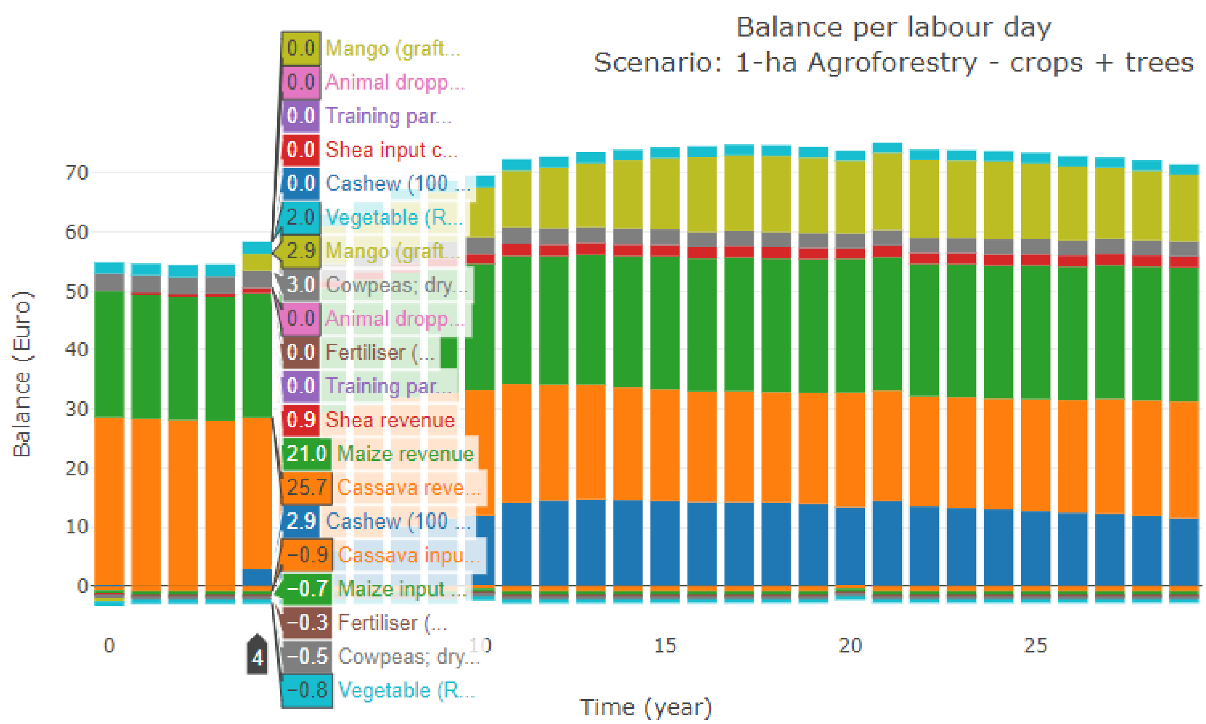
In the agroforestry scenario, the labour per-ha remains relatively stable. Trees require up to 20 or so additional labour days.



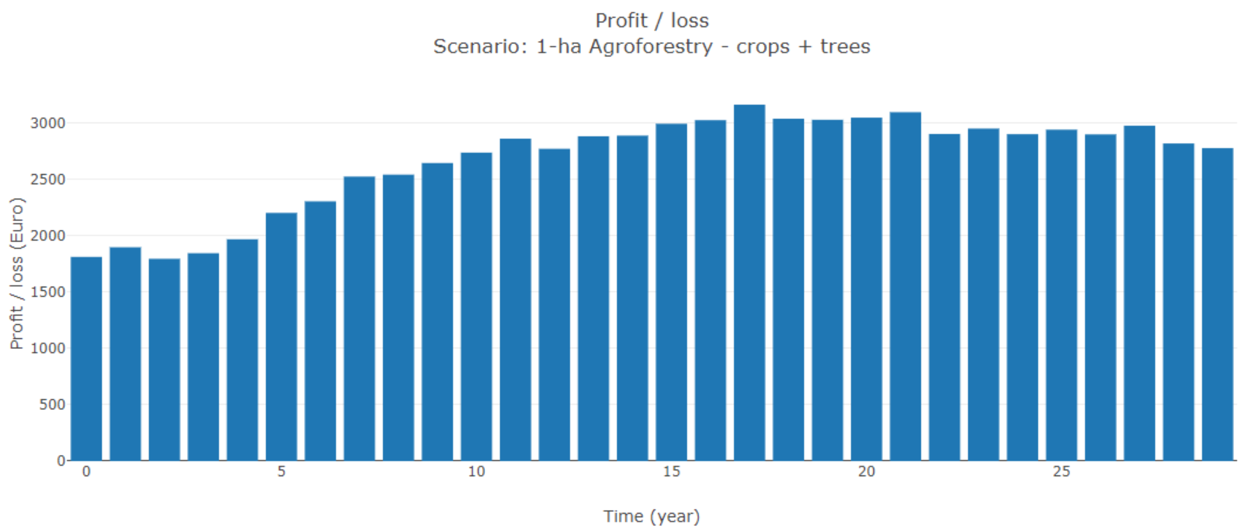
Agroforestry results in a more diverse basket of products coming that the plot produces. This is relevant particularly for women, who always prefer product diversity for home consumption.



Agroforestry leads to an increased monetary value of the basket of products produced. Particularly the fruit production adds considerably to the annual value produced, to the tune of a 25% increase; though only after Year-10.



Consequently, the wage per day also increases particularly through the fruit species taken into the agroforestry system.



All in all, agroforestry increases produced value, with relatively small initial investments. Still it needs to be borne in mind that the above is the optimistic scenario, and that the above figures need further calibration with the real-life situation in the field.

34. **Cooperative-level impact** can be calculated by scaling the 1-ha projections. As project costs are already incorporated in the one-ha calculations, the achievements can be scaled by multiplying the number of hectares. It must be noted though that some additional costs – such as transport, storage facilities, etc. – have not yet been taken into account in this calculation. For cooperatives, we assume that not all farmers adopt proposed climate-resilient measures equally. Table 44 summarises the above-described project scenarios and shows the impact on NPV of just changing cropping pattern, additional technical capacity development, and additional marketing capacity development. When we assume that different farmers in cooperatives adopt such measures to a different degree (as shown in Table 45), we can estimate the project impact at cooperative level.

Cooperatives will be organised based on cropping system foreseen:

Agroforestry is carried out on existing farmers' land, and a full village (100 ha) can organise to shift from 'trees planted' to a 'technical capacity developed' to a 'technical + marketing capacity developed' status. The per-ha NPV thus increases from -$3,300, to $2,200 and $14,500 respectively. When assuming that 80% of farmers improve their technical capacity, and 10% also improves their marketing capacity, the average per-ha NPV increase is $2,800, which is considerable for a household. The cooperative-level NPV then is 100-fold or $283 thousand.

Horticulture is carried out on newly created irrigated land. As per-ha initial investments are ~$7,700, and annual maintenance costs at least 10% of that, just introducing horticulture crops (without additional know-how) is loss-giving. Both technical and marketing capacity are needed to make the enterprise profitable; but then profits are considerable: one ha can have an NPV of $29,000. Horticulture cooperatives will be organised at much smaller scale than agroforestry cooperatives – typically 10 ha. Table 45 shows that for a 10-ha cooperative, an added NPV to the tune of a million US$

is realistic. The calculations have not yet taken into account the purchase and maintenance of a marketing infrastructure, for which additional data are required.

A cooperative managing **Degraded land and river bank restoration** would typically be organised at village level and cover 100 ha. As the prime objective is to protect and restore land, cash earning opportunities are limited. Shea, some Mango, and local fodder trees will be planted. Table 45 (lower table) shows that at project-level, this activity is likely to break-even or provide a modest financial loss when taking project investments (training, seed material) into account. Benefits of this activity are indeed mostly for the downstream 6 million indirect beneficiaries. As investments are born by the project, the enterprise is still likely to be beneficial at the cooperative level; although to assess that would need specific location-wise analysis. When we assume most land managers (40%) to be able to maintain the plantation and another fraction (20%) to be able to sell products, the activity has a positive NPV of almost $1000/ha, or $100,000 for a 100-ha cooperative. This result however depends greatly on the assumed success of training in the project.

Section 8. Scaling farm-level to project-level impact

35. Benin is divided into 12 departments (Figure 1). In terms of population (Figure 7), Atlantique (Department 10 in Figure 1) is the largest department followed by the departments of Borgou (Department 4) and Oueme (Department 12).

Figure 7: Departments of Benin

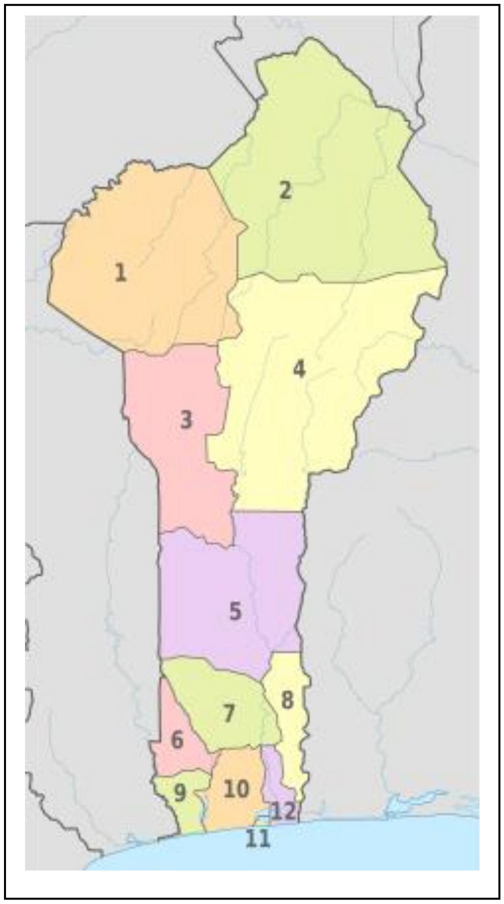


Table 33: Population of Benin Departments in 2013

Map #	Department	Population	Area (km2)
1	Atakora	772,262	20,499
2	Alibori	867,463	26,242
3	Donga	543,130	11,126
4	Borgou	1,214,249	25,856
5	Collines	717,477	13,391
6	Couffo	745,328	2,440
7	Zou	851,580	5,243
8	Plateau	622,372	3,264
9	Mono	497,243	1,605
10	Atlantique	1,398,229	3,233
11	Littoral	679,012	79
12	Oueme	1,100,404	1,281
	Total	**10,008,749**	**114,259**

Source: Institut National de la Statistique et de l'Analyse Économique (INSAE). 2016. Population Census 2013 Report.

36. The departments are subdivided into 77 communes (Figure 2). Communes populations are presented in Figure 8.

Figure 8: Communes of Benin

Table 34: Departments and Communes and Population in 2013

(yellow highlighting indicates communes included in the project)

Department	Commune	Population	Department	Commune	Population
Atakora	Boukoumbe	82,450	Zou	Abomey	92,266
	Cobly	67,603		Agbangnizoun	72,549
	Kerou	100,197		Bohicon	171,781
	Kouande	111,540		Cove	51,247
	Materi	113,958		Djidja	123,542
	Natitingou	103,843		Ouinhi	59,381
	Pehunco	78,217		Za-Kpota	132,818
	Tanguieta	74,675		Zagnanado	55,061
	Toucountouna	39,779		Zogbodomey	92,935
Alibori	Banikoara	246,575	Plateau	Ifangni	110,973
	Gogounou	117,523		Adja-Ouere	116,282
	Kandi	179,290		Ketou	157,352
	Karimama	66,353		Pobe	123,677
	Malanville	168,641		Sakete	114,088
	Segbana	89,081	Mono	Athieme	56,483
Donga	Bassila	130,091		Bopa	96,281
	Copargo	70,938		Come	79,989
	Djougou	267,812		Grand-Popo	57,636
	Ouake	74,289		Houeyogbe	101,893
Borgou	Bembereke	131,255		Lokossa	104,961
	Kalale	168,882	Atlantique	Abomey-Calavi	656,358
	N'Dali	113,604		Allada	127,512
	Nikki	151,232		Kpomasse	67,648
	Parakou	255,478		Ouidah	162,034
	Perere	78,988		So-Ava	118,547
	Sinende	91,672		Toffo	101,585
	Tchaourou	223,138		Tori-Bossito	57,632
Collines	Bante	107,181		Ze	106,913
	Dassa	112,122	Littoral	Cotonou	679,012
	Glazoue	124,431	Oueme	Adjarra	97,424
	Ouesse	142,017		Adjohoun	75,323
	Savalou	144,549		Aguegues	44,562
	Save	87,177		Akpro-Misserete	127,249
Couffo	Aplahoue	171,109		Avrankou	128,050
	Djakotomey	134,028		Bonou	44,349
	Klouekanme	128,597		Dangbo	96,426
	Lalo	119,926		Porto Novo	264,320
	Toviklin	88,611		Seme-Kpodji	222,701
	Dogbo	103,057			

Source: Institut National de la Statistique et de l'Analyse Économique (INSAE). 2016. *Population Census 2013 Report*.

37. On the basis of recent survey work, INSAE has calculated population estimates for the period 2014-2030 for all communes of the country. It may be noted that projected annual population growth rates for the period 2013-2020 as estimated from this recent national survey work are significantly higher than population growth rates presented in the *UN World Population Prospects – 2019 Revision*. INSEA's population projections are presented in Table 35. In the calculation of number of beneficiaries in the Feasibility Study of March 2021, the survey data of 2013 are used; so the number of beneficiaries may be even higher if the expected population growth is taken into account.

Table 35: Population Estimates for Project Communes, 2020 and 2030

Department	Commune	Population		
		2013	2020	2030
Donga	Copargo	70,938	86,614	113,775
	Djougou	267,812	326,994	429,536
Collines	Glazoue	124,431	151,928	199,571
Zou	Zagnanado	55,061	67,229	88,311
	Zogbodomey	92,935	113,472	149,056
Total		**611,177**	**746,238**	**980,249**

Source: Institut National de la Statistique et de l'Analyse Économique (INSAE).

38. The UN *2019 World Population Prospects* presents projections of average annual population growth rates over the period of relevance to this economic analysis (2030-2050). These are presented in Table 36 below. Given these annual growth rates (both historical and projected), Benin's population would increase from 10,008,749 in 2013 (per population census) to 12,080,328 in 2020, and then to approximately 23,852,875 in 2050. These numbers represent more than a doubling of Benin's population over the period of analysis.

Table 36: Average Annual Population Growth Rates (projected)[41]

2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
2.51	2.39	2.26	2.12	1.99

39. Assuming that the national population growth rates presented in Table 37 were to apply at the commune level for the period 2030-2050, then we may obtain estimates of population over the period 2030 to 2050 at commune level. Details are presented in the worksheet "Population" of the Excel file.

Table 37: Population Estimates for Project Communes, 2020, 2030, 2040 and 2050

Department	Commune	Population			
		2020	2030	2040	2050
Donga	Copargo	86,614	113,775	143,174	175,429
	Djougou	326,994	429,536	540,526	662,296
Collines	Glazoue	151,928	199,571	251,139	307,716
Zou	Zagnanado	67,229	88,311	111,130	136,165
	Zogbodomey	113,472	149,056	187,571	229,827
Total		**746,238**	**980,249**	**1,233,540**	**1,511,433**

40. The number of direct beneficiaries was estimated using the existing average number of cultivated hectares per household, by considering the number of hectares to benefit from the project, and then by considering the average number of people per household (Table 38). The number of direct beneficiaries is estimated to reach 330,000 people based on the 2013 population, representing 61% of the estimated population of the 5 communes that are directly working in agriculture. This estimate of 330,000 direct beneficiaries is further based on the expected number of people that can live off the target land use type. In the tree and crop land use scenario this is three people per ha. In the vegetables / horticulture for marketing scenario, this is 10 respectively 3 per ha; but, as some crop land gets turned into tree/vegetable land, the here working number of people needs to be subtracted as opportunity costs. The result is provided in Table 6 that provides estimates of the number of direct beneficiaries.

41 Source: United Nations. 2019. World Population Prospects 2019. Population Division. UN. New York.

Table 38: Estimated Number of Direct Beneficiaries based on 2020 population estimates. The figures in blue are project targets[42].

	Copargo	Djougou	Glazoue	Zagnanado	Zogbodomey	Total
Average number of ha per household						
Number of people in the commune (2013)	70,938	267,812	124,431	55,061	92,935	**611,177**
Number of people in the commune (2020)	86,614	326,994	151,928	67,229	113,472	**746,238**
Number of households in the commune (2020)	18,829	71,086	33,028	14,615	24,668	**162,226**
Number of ha cultivated in the communes	32,745	59,110	26,423	27,034	34,244	**179,556**
Targeted acreages	60%	60%	35%	50%	50%	
Small irrigated plots (ha)	571	496	486	70	377	**2,000**
Lowland rehabilitation (ha)	1,359	831	2,603	3,310	897	**9,000**
Implementation of RWH/SWC/AF (ha)	17,717	34,139	6,159	10,137	15,848	**84,000**
Targeted area (ha)	**19,647**	**35,466**	**9,248**	**13,517**	**17,122**	**95,000**
Targeted population						
Population in catchment area (in 2013)	55,227	165,048	71,986	38,038	58,674	388,973
Population in catchment area (in 2020)	67,431	201,521	87,894	46,444	71,640	474,930
% of total population	78%	62%	58%	69%	63%	64%
Nr of beneficiaries /ha small irrigated plots	9.0	9.0	9.0	9.0	9.0	
Nr of beneficiaries /ha lowland rehabilitation	2.0	2.0	2.0	2.0	2.0	
Nr of beneficiaries /ha RWH/SWC	3.5	3.5	3.5	3.5	3.5	
Number of direct beneficiaries	**69,867**	**125,613**	**31,137**	**42,730**	**60,655**	**330,000**
% of direct beneficiaries	21%	38%	9%	13%	18%	

41. Besides the direct beneficiaries, also downstream people will benefit from project activities in the shape of reduced floods; but also the installation of Ouémé valley level governance structures that will play a role in scaling the promoted technologies. Hence the entire Ouémé valley population will indirectly benefit from the project, which makes the total number of indirect beneficiaries around 6 million. Section 52, Figure 13 shows how a changed cover of the target area reduces water off-flow at peak high rainfall, and thus the impact of floods of people living close to the river bed.

[42] See FAO, 2022. Economic Analysis FAO GCF OCRI Single Crop Based Projections 2022-03-nn sheet "Population and Benefits"

Sodjinou (2022) also assessed the popularity of engaging in the different value chains in the OCRI target area. Table 39 shows that maize is the most popular cash crop, followed by most other annuals. The processing and sale of tree products still has potential for growth; 8-18% of the rural population engages in processing and trade.

Table 39. Part (in %) of the population of OCRI-targeted communes engaged in the processing and trading of different products.

Produits	Copargo	Djougou	Glazoué	Zogbodomey	Zagnanado	Moyenne
Amande de Karité	20%	20%	10%	0%	0%	10%
Derives of Cassava	30%	10%	20%	20%	20%	20%
Derives of Maize	40%	20%	30%	30%	30%	30%
Derives of Mango	10%	10%	10%	10%	0%	8%
Derives of Soja	30%	30%	20%	20%	20%	24%
African tree mustard	20%	20%	20%	20%	10%	18%
Yam flower	40%	30%	20%	0%	10%	20%
Palm oil	0%	0%	0%	30%	30%	12%

Source : Sodjinou, results of interviews, February-March 2022

The fact that sizeable groups of the population engage in the sale of tree and crop products shows that the activity is profitable. For this EFA, the field team collected selected data on the individual business cases for value chains to-be-promoted. Table 16 shows provisional data on values along the value chain, as collected early 2022. The Table shows that for products that farmers use as staple food, such as maize, has a value both at farm gate and throughout the value chain. Such products can be sold as excess products, to satisfy subsistence farmers' cash needs. On the other hand, for products produced for the market such as mango and karité, the market price is considerably higher than the farm gate price. Investing in such value chain development is potentially profit generating.
A detailed analysis of the cost structure of processing and marketing is beyond the scope of this study. Yet, to estimate the economic gain of investing in value chain, we assume that of the difference between the minimum Farm Gate Price and the average consumers' price, 50% is processing costs, and 50% is economic gain. Further, we assume that of the produced volume, only 50% is marketed through value chains set up through the Farmers Business Schools; the other 50% is not marketed or marketed through existing channels. This added value is incorporated in the accompanying Excel, five Commune Summary tabs (lines 133-136); and taken into account in the overall financial analysis of the project in the "Indicators for Proposal" tab.

42. As stated above, the project will lead to a shift in land use, as reflected in Table 40. The acreage of vegetables and tree covered areas increase, at the cost of the acreage of annual crops. Yet – due to the intercropping of trees – the total cover of vegetables, annuals and trees increases a few percent. The Tree intercropping rate used is a setting set at 25% for these calculations.

Table 40. Baseline (BAU) and Project Land Use acreages for the project target area

	BAU Vegetables (Ha)	BAU Annuals (Ha)	BAU Trees (Ha)	Project Vegetables (Ha)	Project Annuals (Ha)	Project Trees (Ha)
Copargo	175	7,077	132	350	6,935	395
Djougou	725	13,407	238	1,449	12,742	715
Glazoue	2,011	38,911	730	4,022	37,083	2,190
Zagnanado	424	13,086	266	849	12,728	798
Zogbodomey	724	16,749	345	1,448	16,111	1,035
Project Total	4,059	89,229	1,712	8,118	85,599	5,133
Project Result				4,059	- 3,630	3,421
Total Area			**95,000**			**98,850**

**As intercropping occurs with agroforestry trees, the total single-crop acreage is more than in BAU*

43. When multiplying the per-ha NPVs with the BAU and Project scenario acreages presented in Table 17, we arrive at the project impact per land use scenario by Commune. Table 41 shows the result.

Table 41. Baseline (BAU) and Project Net Present Value (@10% DR) for the five communes for (a) the Land Use acreages, and (b) for all targeted land in total

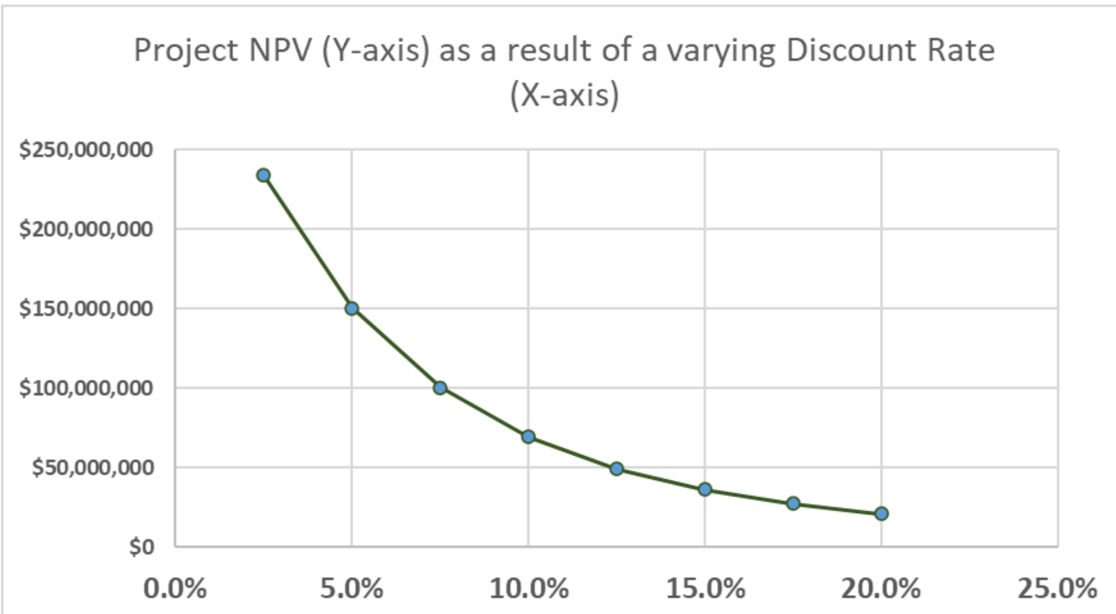
(a)	BAU NPV Vegetables	BAU NPV Annuals	BAU NPV Trees	Project NPV Vegetables	Project NPV Annuals	Project NPV Trees
Copargo	$3,234,899	$43,430,640	$408,564	$6,830,810	$44,239,486	$1,992,244
Djougou	$10,749,465	$66,011,115	$739,077	$22,698,560	$65,041,541	$3,603,894
Glazoue	$17,223,647	$175,724,808	$2,264,108	$36,369,435	$174,505,727	$11,040,271
Zagnanado	$3,173,220	$74,506,836	$825,040	$6,700,568	$75,434,068	$4,023,071
Zogbodomey	$6,122,772	$82,602,676	$1,070,361	$12,928,840	$82,703,543	$5,219,306
Project Total	**$40,504,004**	**$442,276,075**	**$5,307,149**	**$85,528,212**	**$441,924,366**	**$25,878,787**

(b)	Total area cultivated (Ha)*	Total cultivated area Targeted (Ha)	Targeted Area NPV BAU	Targeted Area NPV Project	Targeted Area Project Impact
Copargo	85,016	7,384	$47,074,103	$53,062,540	$5,988,437
Djougou	177,974	14,370	$77,499,657	$91,343,995	$13,844,338
Glazoue	488,125	41,652	$195,212,563	$221,915,434	$26,702,871
Zagnanado	146,538	13,776	$78,505,096	$86,157,706	$7,652,611
Zogbodomey	188,943	17,818	$89,795,809	$100,851,689	$11,055,880
Project Total	**1,086,596**	**95,000**	**$488,087,228**	**$553,331,365**	**$65,244,137**

**There are conflicting baseline acreage reports; but this does not affect the impact calculations of the project as this is based on changes in land use on targeted areas alone*

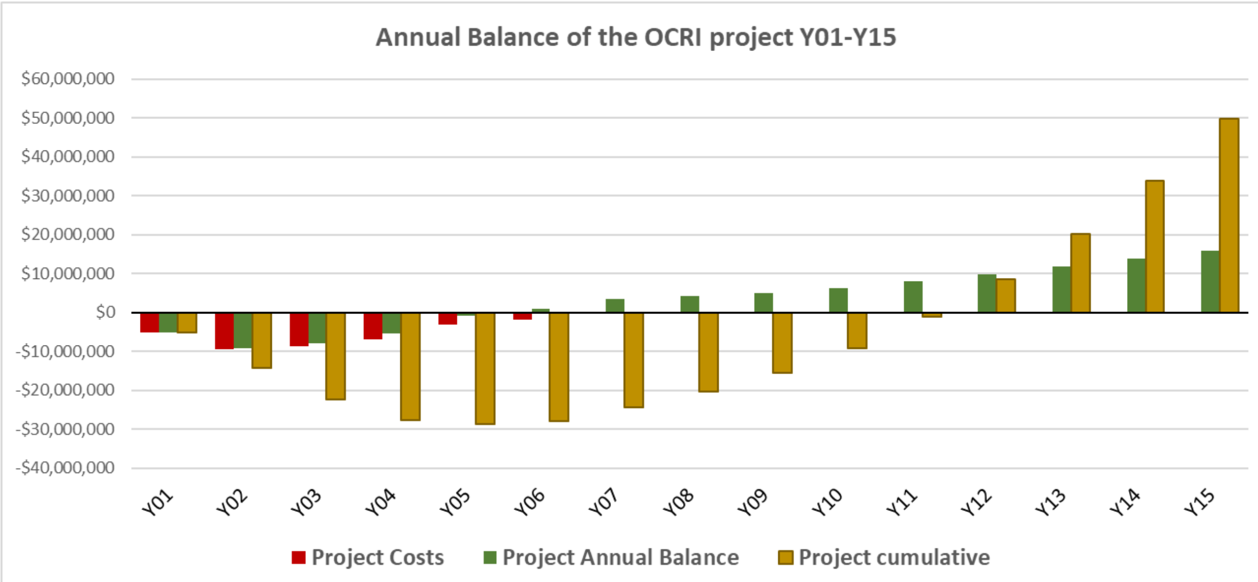
44. The above shows that the Project *Impact* NPV at 10% Discount Rate is around US$ 69.4 million – see also the next Section for the different ways by which the NPV can be calculated. The Project NPV (including costs) is around US$ 39.8 million. This NPV is heavily influenced by the fact that Climate Change takes place gradually, and that the impact of tree planting takes place up to a decade after project start. Therefore we did a sensitivity analysis of the NPV. The Figure shows how the Project Impact NPV changes as a result of the Discount Rate. It shows that the NPV reaches the Project cost of around US$ 35 million, even at a Discount Rate of 15%.

Figure 9. Sensitivity analysis of the influence of the Discount Rate on the Project Net Present Value



45. Figure 10 shows the annual project cost-benefit balance. The project investment is of US$35.3 million, spread over six years. Assuming that farmers keep learning to connect to the market gradually between Y-01 and Y-10, the project breaks-even 11 years after project start. As we assume full market connection, the annual project impact increases considerably after Year 10 to an annual improved production value of around US$ 20 million after Y-14, because by then trees produce to their full potential.

Figure 10. Project Balance: befits minus costs (green) and project costs over the years (red)



46. Table 43 shows that the Project NPV (assuming that the investment is spread over Year 1 – Year 6, and the project *impact* linearly grows in Y-00 to Y-10), with a discounted project investment, is around US$ 91 million; and the IRR then is 20%. Including project costs the NPV then is $62 million[43]. We stick to these values in the Funding Proposal.

47. We further did an agriculture product price sensitivity analysis for project financial impact. Table 42 shows the results. The result is that with a -15% or +15% of price fluctuation across the board, the project remains economically feasible, with IRRs between 15% and 21%.

[43] However, in this way of calculating, project investment is also discounted for, and amounts only US$ 29.9 million. By another way of calculating – by which all investments are in Year 0 (so $35.5 million) - the NPV including project costs is $ 56 million (including investments), and the IRR is 16%.

Table 42. Sensitivity analysis of agriculture product price levels (expected, low, high) on project NPV and IRR, calculated with a discounted and non-discounted project investment

Economic Indicators (NPV @ 10% DR)	*Low price level (80%)*	*Expected price level (100%)*	*High price level (120%)*
Project investment total (not discounted)	-$35,314,576	-$35,314,576	-$35,314,576
NPV Project Impact (discounted for project startup)	$62,352,019	$69,350,435	$76,348,852
NPV Project incl non-discounted investment	$27,037,443	$34,035,860	$41,034,276
IRR Project (derived from direct investment/delayed impact)	13%	14%	15%

NPV Project Investment (discounted)	-$29,487,735	-$29,487,735	-$29,487,735
NPV Project Impact (discounted for project startup)	$62,352,019	$69,350,435	$76,348,852
NPV Project incl discounted investment	$32,864,284	$39,862,700	$46,861,117
IRR Project (derived from startup cash flow / delayed impact	17%	18%	19%

Section 9. Some economic project impact indicators

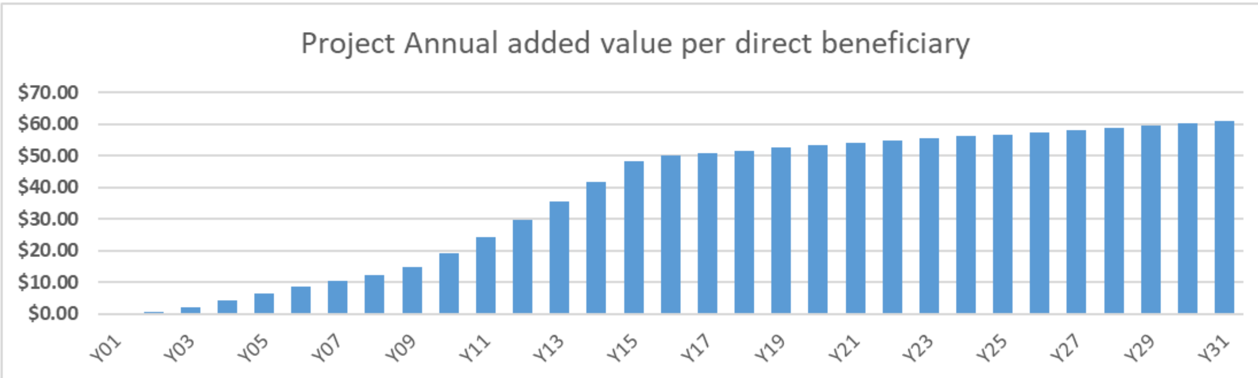
48. **The economic value of climate mitigation**, with an assumed carbon price of US$20 per tCO2e, and a total carbon removal achieved by the end of the tree cover completion (20 years) of 9,000 ha of additional trees, that sequester 1.3 t CO2e per ha per year. This makes 1,753,628 tCO2e, the NPV of carbon removal is $14,929,624. See the accompanying file "*Economic Analysis – Single Crop based Projections*"; tab "*indicators for proposal*" line 137.

Table 43. Economic Indicators of the project cash-flow

Number of people in the commune (2020)	746,238
Number of direct beneficiaries	330,000
Total Households benefiting from the project	71,739
Fraction of total commune population benefitting	44%
Total costs	$35,314,576
Costs per beneficiary	$107
Total population of Bénin	12,000,000
% of Bénin directly benefiting	2.8%
Economic Indicators (NPV @ 10% DR)	*expected price level*
Project investment total (not discounted)	-$35,314,576
NPV Project Impact (discounted for project startup)	$69,350,435
NPV Project incl non-discounted investment	$34,035,860
IRR Project (derived from direct investment/delayed impact)	14%
NPV Project Investment (discounted)	-$29,487,735
NPV Project Impact (discounted for project startup)	$69,350,435
NPV Project incl discounted investment	$39,862,700
IRR Project (derived from startup cash flow / delayed impact	18%
NPV Project Impact on Carbon Removal	$14,929,624
NPV Project Impact (financial + Carbon Removal)	$84,280,059

49. The impact farmers' income is calculated by dividing the annual project impact (in increased production value over the baseline) divided by the number of direct beneficiaries. If we assume a daily wage of FCFA 3000-5000 (~US$ 9, upper value is chosen), this will lead to an **additional employment of 11,000 jobs by year 10 after project start, and almost 17,000 additional jobs by year 30 after project start**.

Figure 11. The impact of the OCRI project on the annual income of project beneficiaries



50. **Project-level impact** can be calculated similar to cooperative-level impact. The accompanying Excel sheet (*Economic Analysis FAO GCF OCRI FarmTree Time Series Processing*) has a tab "Dashboard Project All" that allows for project impact calculations. Table 46 provides an example of cooperative-level impact. Based on the indicated distribution of training success, the project NPV (at 10% DR) is around US$ 243 million; this however is highly dependent on the adoption level of the proposed climate-resilience measures, and does not yet take climate change into account. For now however we chose to carry out project-level economic assessment based on projections that do take climate change into account. Section 14 and further provides overall project impact estimates.

51. **The synergy between OCRI/GCF interventions and GOB/IFAD interventions** is clearly shown in the different levels of project activity implementation. Assuming (as stated above) that GCF focuses more on infrastructure, introduction of trees and irrigation, and climate-resilient capacity building only just makes a break-even in terms of NPV. While adding the commercialisation and marketing component, particularly for Agroforestry and Horticulture activities become entrepreneurial activities, that farmers will sustain and scale based on their expected benefits.

Table 44. Summary of project performance on a 1-ha basis; and sensitivity analysis of the "full intervention" option. The middle table indicates the impact on NPV of increasing intensity of project intervention: (a) only changing crops; (b) (a) PLUS technical capacity development (c) (a)+(b) PLUS marketing capacity development.

		Impact on BL NPV by intervention level (10% DR)				*Sensitivity full intervention to …*			
Baseline => project option (1-ha plot)	Baseline NPV	Baseline	Crop change impact	Crop change +Cap-Dev impact	Full: Crop change +Cap-Dev +Market-Dev impact	Production MINUS 20%	Production PLUS 20%	Input Costs MINUS 20%	Input Costs PLUS 20%
Cropped dryland => Agroforestry	$1,176	$0	-$3,340	$2,157	$14,473	$8,836	$22,462	$15,822	$12,139
Cropped dryland => Horticulture	$1,176	$0	-$42,928	-$58,571	$29,068	-$4,436	$64,924	$33,987	$5,355
Degraded Land => Restored land	-$968	$0	-$2,467	-$613	$11,051	$5,944	$14,223	$10,158	$8,035

Table 45. Scaling of plot performance to cooperative level. The middle Table shows the distribution of hectares with different levels of proposed interventions: all adopt change-of-crops; part also develops technical capacity, and yet another part also develops marketing capacity. The resulting cooperative-levels NPVs are displayed in the right-table.

		Realised acreage (ha)			*Realised additional NPV (US$; 10% DR)*			
Cooperatives' activity	Target (ha)	Crop change	Crop change + Cap-Dev	Crop change +Cap Dev + Market-Dev	Land cover change	LCC+ Cap-Dev	LCC +Cap Dev + Market-Dev	Total
Cropped dryland => Agroforestry	**100**	10	80	10	-$33,404	$172,579	$144,730	$283,905
Cropped dryland => Horticulture	**10**	0	3	8	$0	-$146,428	$218,010	$71,582
Degraded Land => Restored land	**100**	40	40	20	-$98,671	-$24,505	$221,028	$97,852

Table 46. Scaling of plot performance to project level. The middle Table shows the distribution of hectares with different levels of proposed interventions: all adopt change-of-crops; part also develops technical capacity, and yet another part also develops marketing capacity. The resulting project-levels NPVs are displayed in the right-table[44].

			Targeted acreage (ha)			*Realised additional NPV ('000 US$) (DR 10%)*			
Activity	Target (ha)	Total	Crop change	Crop change + Cap-Dev	Crop change +Cap Dev + Market-Dev	Crop change	Crop change + Cap-Dev	Crop change +Cap Dev + Market-Dev	Total
1-ha Cropped dryland => Agroforestry	**84,000**	100%	37,800	37,800	8,400	-$87,954	$147,098	$136,141	$195,284
1-ha Cropped dryland => Horticulture	**2,000**	100%	-	500	1,500	$0	-$23,355	$61,394	$38,039
1-ha Degraded Land => Restored land	**9,000**	100%	3,600	3,600	1,800	-$8,206	-$1,532	$20,229	$10,491
						*Project NPV **('000 US$)***			**$243,814**

[44] The tree-crop integrated FarmTree® Model used here is not yet fully calibrated for the project area. Therefore, for project-level impact calculations, we stick to the single species projections, as presented in Section Section 6.

52. **We used the FarmTree® Model for estimation of project economic performance**. The foreseen Agroforestry activities as planned for the 95,000 ha provides a mix of production (both for subsistence and for marketing), environmental (carbon, erosion and flood control etc.) and social (employment) services. For estimating such services by OCRI, we applied the FarmTree® Tool[45] that projects the performance of Agroforestry plots. For this study, we carried out a limited analysis for the approximate 9,000 ha of additional tree cover that is spread over the 95,000 ha now under annual crop cultivation. We assumed 10 years of historic weather data of middle-Ouémé, a 1-ha plot with a 10% slope, about 180 kg of NPK through animal droppings and fertilisation, competent farmers (80% of potential) and ready access to the market. In order to compare Business as Usual and Project scenarios, we assumed that trees were planted in Year 10 of the projection. For visibility reasons, we show the results of the 9,000 ha with tree planting rather than the total 95,000 ha, as the effect of tree planting in the latter would be less pronounced. The different social and environmental impact indicators are displayed in Table 47.

Table 47. Some outcomes of the environmental and social impact as derived from plot projections

Impact indicator	Foreseen impact
Soil erosion reduction	The overall reduction of soil erosion as a result of Agroforestry will be 95,000 ha * 9 tonnes soil / y ~855,000 tonnes soil / y. This reduces downstream damage to fields and other assets.
Production diversity for resilience	At tree planting, the diversity of production goes up, from 4 to 9 primary product types
Gender-segregated labour division	As men work more on trees (planting, pruning etc) relatively to women - who do most staple food work - the work balance will go more towards men (from 75%-25% to around 50%-50%).
Carbon sequestration	Every year, around 7 tonnes of biomass per ha tree planted is sequestered; which is an equivalent to (CO2e weight/ Biomass weight ~165%) of around 11.6 tonnes CO2e per ha per year. Over the entire project period some 860,000 tonnes CO2equivalent will be sequestered in Agroforestry stands.

[45] See https://www.dibcoop.nl/farmtree or a separate annex. The FarmTree® Tool provides indicators for production, financials and environmental performance of mixed cropping systems and landscapes. The here shown indicators have been derived from an internal consultancy version and based on the internal FarmTree.earth database of Components of Agroforestry Systems (CAFS-Database)

Figure 12. The impact of tree planting in Year 10 on the cover of 9,000 (of the 95,000) ha where trees get planted.

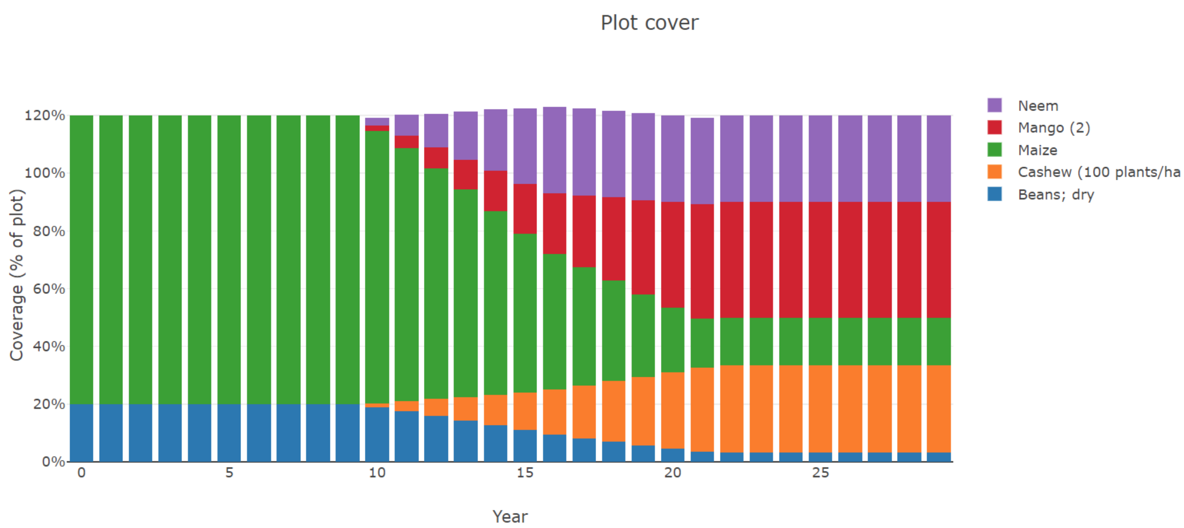


Figure 12 shows the impact on plot cover of planting trees in Year 10. Note that both maize-beans (annual) and trees allow for intercropping, leading to a more-than-100% plot cover. Even with trees on the plot, some space will be available for intercrops such as maize and beans.

Figure 13. The impact of tree planting in Year 10 on the soil water balance on 9000 (of the 95,000) ha where trees get planted.

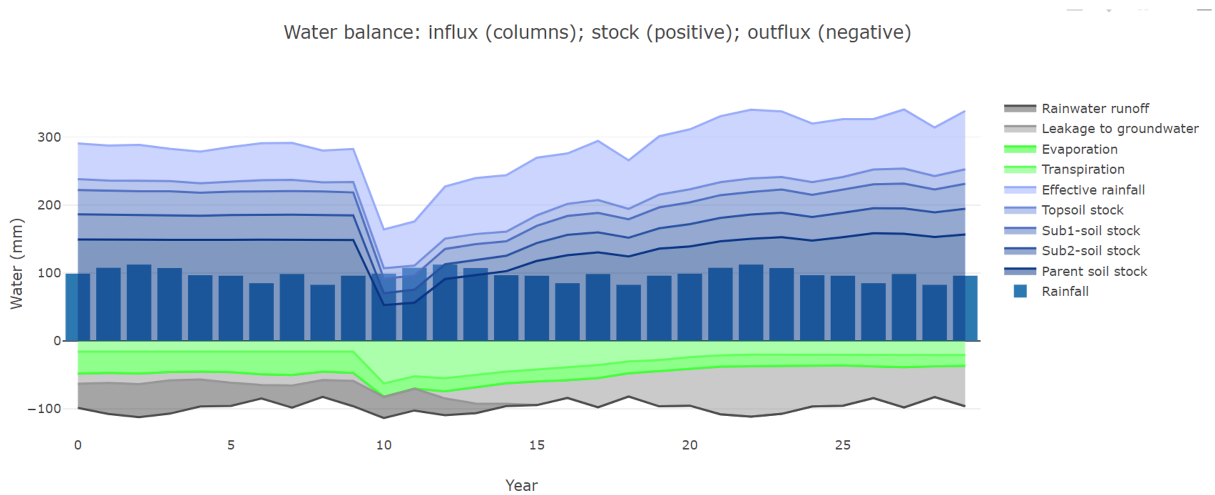


Figure 13 shows the impact of trees on the water balance of plot soil, which is relevant for climate change. After planting trees in Year 10, trees take water out of the deeper soil layers; but trees also lead to reduction of evaporation, leading to a more stable soil humidity in the course of the years. As trees prevent water from runoff (low dark grey layer), and thus erosion will be reduced. This can be seen in Figure 14, that shows that soil erosion goes down from around 9 tonnes per ha per year to zero. In the full 95,000 ha, a 5% tree cover will reduce the erosion by approximately 50%. This means that the **overall reduction of soil erosion as a result of Agroforestry will be 95,000 ha * 9 tonnes soil / y ~855,000 tonnes soil / y. This reduces downstream damage to fields and other assets.** This also means a reduction in loss of soil fertility.

Figure 13 also shows that the discharge of water during peak rain will be reduced drastically in the treated 95,000 ha. Although we can in principle quantify this, the model needs more field infomation to provide more accurate estimates.

Figure 14. The impact of tree planting in Year 10 on soil erosion on 9,000 (of the 95,000) ha where trees get planted.

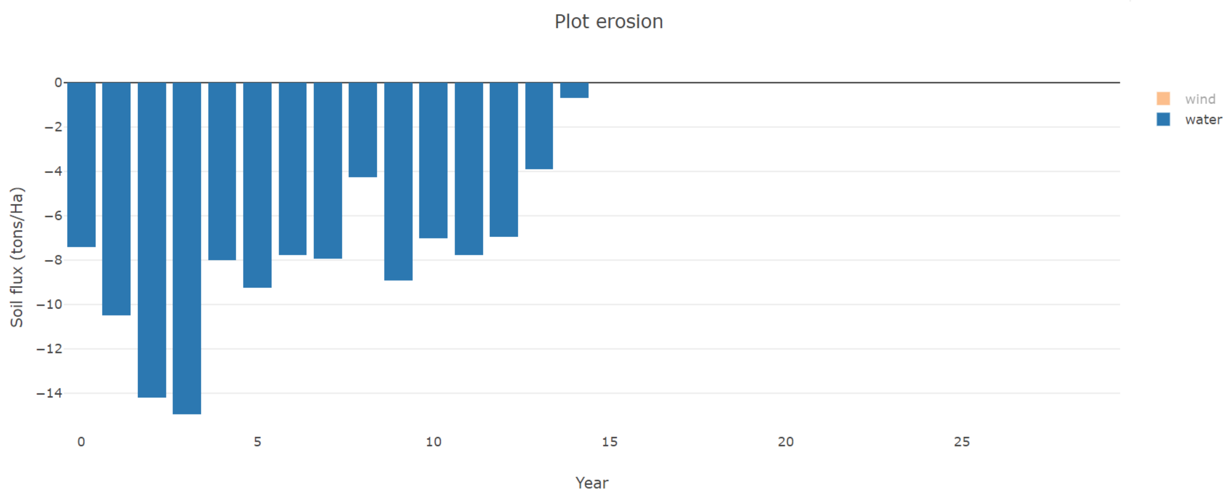


Figure 15 shows the impact of agroforestry on productivity. As we assume that a 'normal' maize-bean (niebé) intercrop produces staplefood and pulses, but also low and high quality fodder, in the baseline four different products are being produced. At tree planting in year 10, the diversity of production goes up, from 4 to 9 primary product types, which impacts farm resilience to climate change. Expected production volumes are derived from another data set and calculation routine, as reported above.

Figure 15. The impact of tree planting in Year 10 on the productivity of 9,000 (of the 95,000) ha where trees get planted.

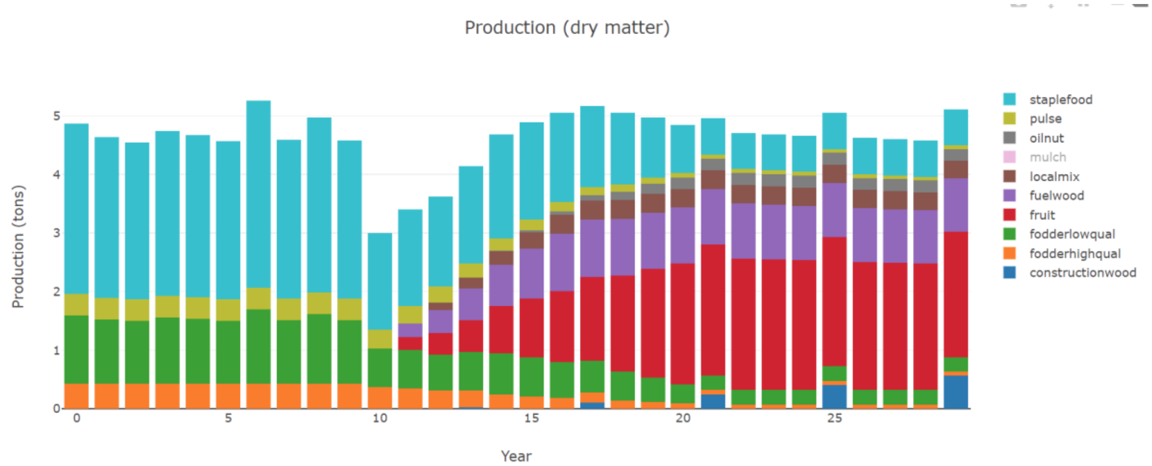


Figure 16 shows the impact of tree planting on on-farm labour. As we can see, labour requirements go slightly up, from ~ 120 days per ha per year (for maize-niébé) to ~135 labour days per ha per year (for the tree-maize-niébé intercrop). **As men work more on trees (planting, pruning etc) relatively to women - who do most staple food work - the work balance will become more equal (from 75%-25% to around 50%-50%).** This analysis needs to be backed up with research on local gendered work division; this assessment is based on general African data.

Figure 16. The impact of tree planting in Year 10 on gendered labour requirements of 9,000 (of the 95,000) ha where trees get planted.

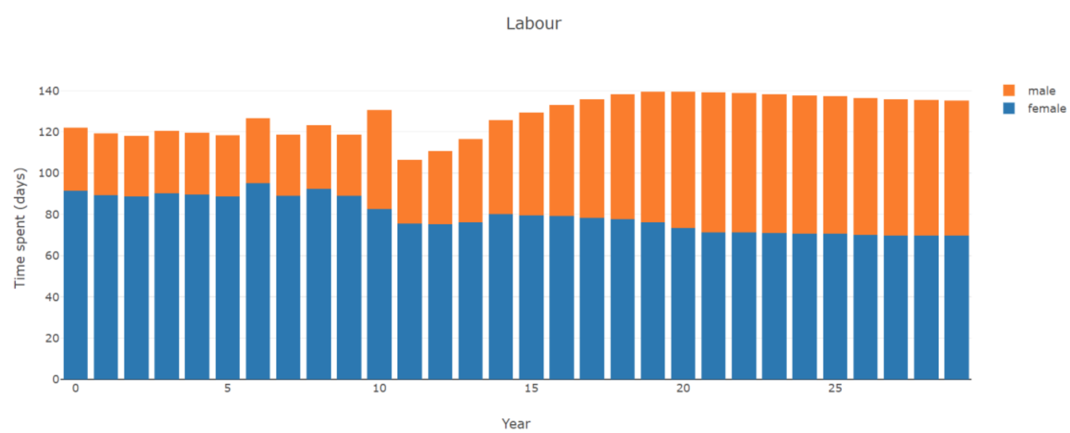


Figure 17 shows how planting trees in Year 10 makes the biomass on the plot grow from around 10 tonnes biomass to 140 tonnes biomass after 20 years, in the 9,000 ha tree-covered land. This means that **every year, around 7 tonnes of biomass per ha is sequestered; which is an equivalent to (CO2e weight/ Biomass weight ~165%) of around 11.6 tonnes CO2e per ha per year**.

Figure 17. The impact of tree planting in Year 10 on the standing biomass of 9,000 (of the 95,000) ha where trees get planted.

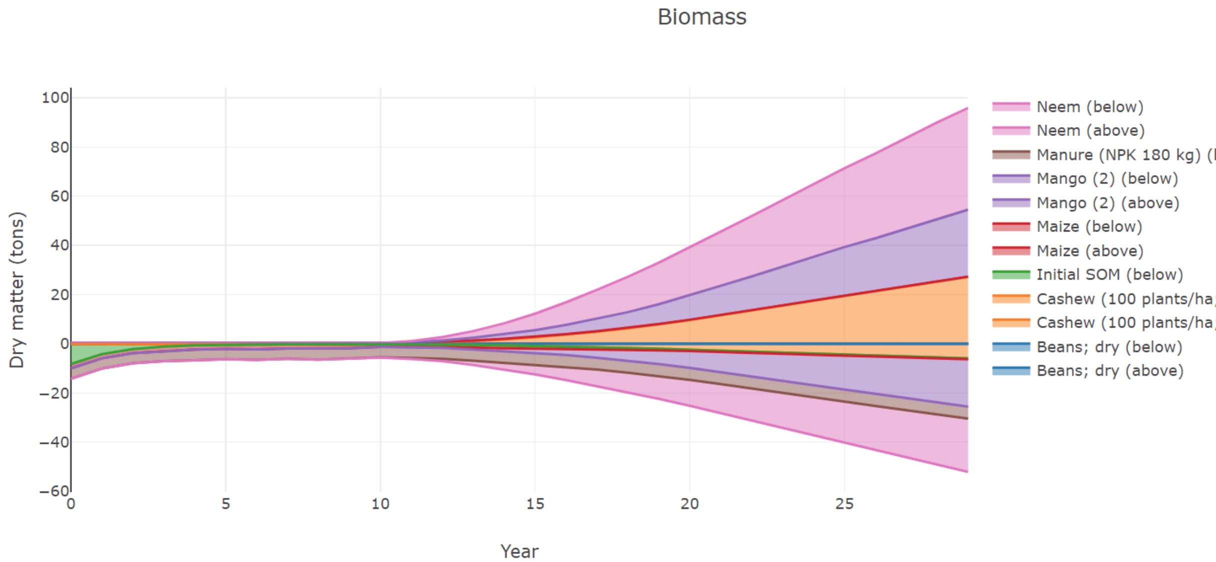


Table 48 shows the consequent CO_2e carbon sequestration calculations for the entire project period. Over the entire project period some 860,000 tonnes CO2equivalent will be sequestered in Agroforestry stands.

Table 48. Estimated additional tCO2e sequestration during the project life time

tCO2eq/ ha /year	sequestration stablisation year	Additional ha of trees in target area	tCO2eq project per year	tCO2eq project after 20 year
11.6	**20**	**9,000**	**104,400**	**2,088,000**