MADAGASCAR
DEFIS+

ANNEX 2.c

INFRASTRUCTURE FEASIBILITY STUDIES SUMMARY

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Introduction

This Annex provides a summary of some of the feasibility studies for the infrastructure sites such as roads and irrigation schemes that are being prioritised. It elaborates on the work that will be done in the different regions based on the current status of the infrastructure and the climate risks in the regions. The studies are being produced on a rolling basis following the prioritisation of the infrastructure sites as detailed in the Full Proposal. The main climate risks and hazards faced in the regions where the project will be implemented are provided in Annex 2a and 2b. This Annex also outlines the steps followed in the feasibility studies for the irrigation schemes. The list of identified rural roads and irrigation perimeters prioritised under DEFIS is included as an appendix to this Annex. The Appendix also provides a brief description of the types of works envisaged for the climate proofing of the infrastructure.

Madagascar is ranked 3rd in the world among the countries most highly exposed to tropical cyclones and first among African countries. These cyclones and the occurrence of rains of very high intensity and sometimes long duration cause many floods throughout the country, especially in areas with relatively high risk, such as the areas that DEFIS+ partly covers. Road infrastructure is a priority target because of the scale of damage after a flood. Therefore, the climate proofing of the roads will entail works related to improving the robustness of the infrastructure to withstand climate related shocks.

A road protection guide against flooding exists in Madagascar. This guide aims to increase the safety of road infrastructures against damage related to floods, secure the investments made in road infrastructure, and propose the use of materials that are more resistant and durable. By applying the standards articulated in the guide, the lifetime of the infrastructure to withstand a flood increases to 100 years, and a long-term improvement of around 75% on the risk according to a statistical and semi-probabilistic evaluation can be estimated. To the climate proofing activities will be added the application of green roads for water techniques developed by Meta Meta and other partners. Green roads for water solutions must be adapted to the landscape and context of each agro-ecological zone.

While climate proofing increases the up-front costs of road rehabilitation, climate-resilient roads could be cheaper over their lifetime since they are designed to last longer and cost less to maintain. Current costs related to climatic shocks and maintenance are high, as most infrastructure maintenance is largely caused by climate variability. Therefore, using design standards that take climate projections into account would also contribute to the climate resilience of the road infrastructure.

The irrigation schemes selected to be rehabilitated were not constructed according to Malagasy standards for the construction of hydro-agricultural infrastructures against floods within the framework of the technical life of the infrastructure project. Therefore, they have minimal protection from silting, which is an aggravating factor, leading to the destruction of infrastructure at a flood level lower than that for which they are designed. Most schemes also use open, unlined canals and have minimal water control structures. Therefore, the rehabilitation will entail application of the improved standards and on the other hand, the implementation of works that are resilient to climate change will contribute to reducing losses in flow which will be used to serve more cultivable areas.

I. Roads

A. Overview

The table below shows roads that will be constructed and rehabilitated. It also indicates key characteristics of these roads.

The major climate proofing works on these roads will be to adapt the use of green roads for water principles and include channels in rubble masonry or reinforced concrete; reinforced concrete pavement; cobblestone or studded pavement; ridge ditches; underpass; infiltration wells. However, climate proofing works on the roads will only be done on hotspots, and not entire lengths. The exact hotspots and lengths will be determined during the feasibility studies.

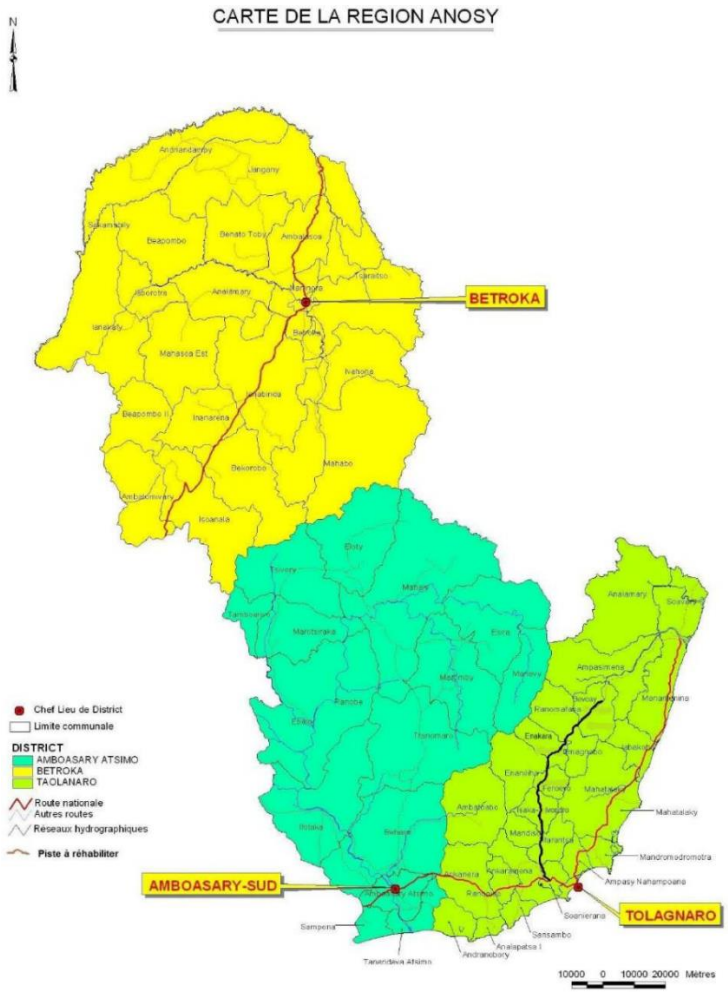
Region	District	Road Section	Length (km)	Estimated Costs ($)
Amoron'i Mania	Ambatofinandrahana	Antsahakely-Soavina-Ambondromisotra-Ambatomifanongoa	60	2 658 000,00
Haute Matsiatra	Vohibato	Mahasoabe-Andranomiditra-Ihazoara-Ampatsy Ampangabe	36	1 594 800,00
Haute Matsiatra	Ikalamavony	RN 42-Solila	25	1 107 500,00
Haute Matsiatra	Ikalamavony	Ikalamavony-Ambatomainty	50	2 215 000,00
Ihorombe	Ihosy	Ilakakabe-Mahabo	34,5	1 528 350,00
Fitovinany	Manakara	Marofarihy-Lokomby	60	2 658 000,00
Atsimo Atsinanana	Vangaindrano	Soamanova-Iara	42	1 860 600,00
Atsimo Atsinanana	Farafangana	Anosivelo-Evezo	15	664 500,00
Fitovavy	Vohipeno	Andemaka-Sahalava	20	886 000,00
Vatovavy	Nosy Varika	RN24-Ambohinihaonana	30	1 329 000,00
Fitovavy	Vohipeno	Mahabo-Ankarana	35	1 550 500,00
		Total	**407,5**	**18 052 250,00**

B. Details on some selected roads

1. Rural Road connecting Tsivory of Amboasary District, Districts of Betroka and Amboasary, Region of Anosy

1.1 Location

This study concerns the rural road connecting Mahabo PK 00+000 to Tsivory PK 56+425 a part of the RNC 6 Betroka - Mahabo - Tsivory in the districts of Betroka and Amboasary Sud, Anosy Region.



The total length of the road to be rehabilitated is 56.425 km. It affects a population of approximately 282,258 inhabitants for the five Communes directly concerned, including 48,254 Tsivory, 20,400 Elonty, 16,242 Mahabo, 17,453 Ivahona, 86,800 Betroka, and the five Communes indirectly of which are 16,687 Ebelo, 16,530 Marotsiraky, 20,243 Imanombo, 20,332 Mahaly and 20,317 Ianambinda.

Along the entire length of the rural road, two (2) types of soil constitute the platform with a predominance of clayey materials (Clayey materials 71%; sandy materials 29%). the second category is made up of the subsequent regions Anosy at 12.3 ton/ha/yr

Climate projections (see Annex 2b, Feasibility Study): Anos, is one of the regions where the Temperate group of climates is prevalent over more than a third of the area. In this group, the

present climates are the Humid subtropical climate, the Temperate oceanic climate, the Monsoon-influenced humid subtropical climate and the Subtropical highland climate. The Tropical group of climates is prevalent over more than 33% of the area. The median change in precipitation for the rainy season between 1989 and 2018 is approximately 2% in Anosy compared to precipitation in the reference period (defined as 1979-2008). With a mean number of days subject to extreme wet events decrease of -0.8 day, Anosy is in the third cluster with projected increased changes. In this cluster, all the regions are located in the Eastern part. Mean temperature in the dry season has increased from 0.29°C in Anosy between the 1979-2008 (the reference period) and 1989-2019.

With an average temperature 1.40°C (High Confidence), Anosy falls in the third cluster, which looks towards the most change. In this cluster, more than half of the regions are coastal. In terms of wind speed, Anosy is classified under the second cluster having 52 hours with an average wind speed of 92knt. With regards to extreme wind events, having a mean number of days subject to extreme wind events increase of 1.6 days annually within the 2026-2055 period, Anosy is within the first category, which faces the least change.

1.2 Current situation

The eleven Communes that depend on this rural road have high potential for agricultural productivity that can lead to food and nutrition security as well as additional income to the population, if access to markets can be secured, through construction of this road. In these communes served by this road, 70-80% of agricultural production is for household consumption, and the remaining 20-30% of the produce is sold for household income. Farming in these communes is predominantly rice cultivation, done using traditional techniques, and cropping is done twice a year. However, the current state of the road linking these eleven Communes is a handicap for transportation of agricultural produce and access to basic services. The state of the road worsens during climate shocks as heavy rainfall, which makes it impassable. The surface of the road usually retains water and becomes slippery restricting access for vehicles and bicycles.

The surface of the roadway shows significant degradations; these are mainly manifested by longitudinal gullies as a result of the excess water that uses the road as a channel. The state of the road increases the travel times on the roads and the wear and tear of the few vehicles that venture on the roads. This results in increased cost of transportation for communities.

1.3 Proposed solutions

The road is prioritised for rehabilitation given its importance in the access to basic services and the economic development of these Communes through agricultural market access. One of the criteria for prioritisation of the rehabilitation is the subsequent proper management and maintenance by the AUP (Association of Road Users) to ensure the roads sustainability. The AUP is a permanent structure for the management and maintenance of the rural roads located at the level of the Communes, headed by the regional authorities.

The surface works will essentially consist of the rehabilitation of the roadbed through light and heavy reprofiling works, and contribution of selected materials (Macadam, MS).

In fact, for the execution of the earthworks and the surface, it is necessary to have a brigade of heavy equipment if an effective delivery is desired in the execution time. The planned earthworks are classic and will consist of:

- Reprofiling of the roadway platform;
- Purges, generally at low points where alluvial materials carried by rainwater or the presence of sloughs accumulate;
- Backfilling and/or raising of the purged areas and in the right of the engineering structures (scuppers), with all the sujétions;
- Placement of selected materials e.g. macadams.

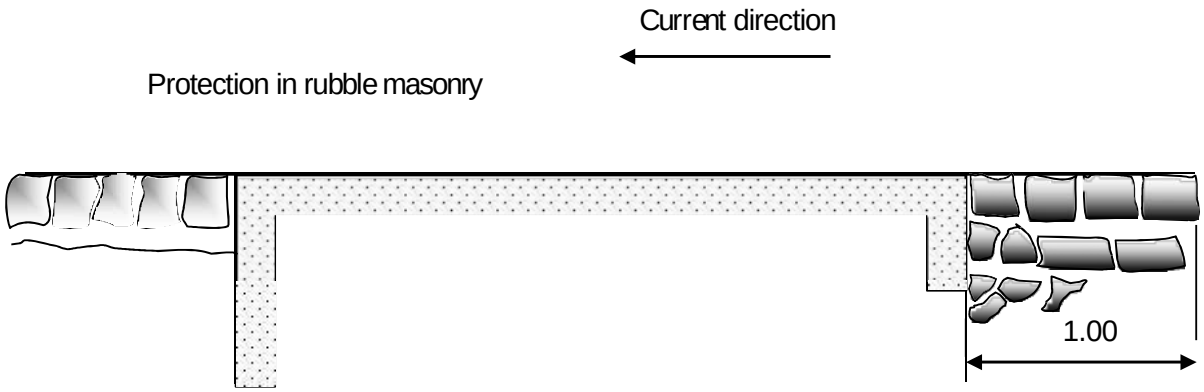


Figure 1: *Concrete pavement and gutter*

All these works can be done mechanically or manually as well as the extraction and transport of soil for backfill. It is advisable to use mechanical compactors for compaction.

Ditches:

- Lateral in earth and will be of triangular profile of 1,00 m x 0,40 m with fascines ;
- Masonry with a square profile of 0.40 m x 0.40 m or 0.50 m x 0.50 m, filled with
- mortar dosed at 300 kg/m3 ;
- Of earthen ridge and will be of trapezoidal profile of 0,60 m x 0,40 m x 0,40 m with benches.

Outfalls/Swales:

- Installed at useful distances for the evacuation of runoff water.

Scuppers:

- Various dimensions according to the results of the hydraulic studies and the flows:
    - D1 : 0,80 m x 0,80 m ;
    - D2 : 1,00 m x 1,00 m ;

Mortar dosed at 300 kg/m3 and concrete dosed at 350 kg/m3.

Earthworks will entail:

- weeding and clearing of the right-of-way of the route;
- pruning tree branches;
- excavation to correct the geometric shape of the road surface;
- back filling of flood-prone areas.

Drainage works

- Creation of lateral and divergent ditches consolidated by fascinations (slope<3%);
- Creation of masonry ditches so that they can evacuate the wild water which tends to cross the track, especially in the sections with a considerable slope (slope >6%);
- Installation of type D1 culverts;
- Riprap and the placement of gabions or riprap at the outlet of the culverts (downstream side) is very important to offset the effect of the runoff.

Road works and protection

The road construction works, the nominal width of which is set at 5m, consist of:

- Restoration of the pavement by light or heavy reprofiling according to the standard profile on a certain section.
- Installation of wearing course in materials selected according to the characteristics of the ground of the platform.

Concerning protective works, these are:

- Vegetating of the embankments of the dykes;
- Construction of masonry walls;
- Reduction of erosion at the level of landslides
- Crossing structures will be created on very violent water crossings during the rainy season.

1.4 Estimated total costs

Cost of the RNC 6 Section project Mahabo PK 00+000 - Tsivory PK 56+425 (Ariary)	Number of population served	Cost per capita (Ariary)	Cost per Km (Ariary)
6 618 952 656,95 Ar	282 258	23 450,00	117 305 319,57

Sub-project cost in USD: 1 505 532.38

It is important to preserve the environment to ensure the sustainability of the rehabilitated road. An environmental monitoring and follow-up program will be implemented during the different phases of the project. The use of the road calls for permanent vigilance by the AUP (Association of Runway Users) and the authorities of the eleven Communes, supported by the regional authorities. Community responsibility and ownership are needed to ensure the maintenance of the trail. This responsibility concerns the AUP, the mayors, the municipal elected officials, the authorities in the region, including the economic operators and the direct users (drivers, carters, travelers, etc.).

2. Rural road connecting Soanierana - Ranomafana – Manantenina, District of Taolagnaro, Region of Anosy

2.1 Location

The total length of the rural road to be rehabilitated is 49,000 km linking Soanierana - Isaka Ivondro - Fenoevo (Trocon 1 of RIP 118 Soanierana - Ranomafana - Bevoay). It affects a population of about 117,363 inhabitants for the twelve communes concerned, including 6,515 Soanierana, 11,005 Ifarantsa, 6,225 Mandiso, 17,453 Isaka Ivondro, 6,800 Fenoevo, 6,687 Enaniliha, 10,530 Emagnombo, 9,171 for Enakara, 18,317 for Ranomafana, 12,960 for Bevoay, 6,500 for Ampasimena and 5,200 for Tanandava.

Climate and rainfall: The Anosy Region is marked by the presence of a rainfall fault on either side of the Ranopiso pass. The wet eastern slope is permanently exposed to the breath of the trade winds, while the western slope is much drier. More specifically, in the Manampanihy and Efaho watersheds, the annual rainfall is 1892.2 mm. With a value of 1663.5 mm, it is between the months of November and April that the rain is abundant there. During this period, the average monthly temperature is 24°C. From April, the temperature will drop considerably to reach 20°C in August.

Relief and landscape: The right-of-way of the road track to be rehabilitated is located in a low altitude coastal plain (100 to 200 meters) surrounded by low hills from Savoka to Ravinala. In this area, the track even crosses the slope of one of said surrounding hills whose summit is 900 meters above sea level.

Soil type: From Soanierana to Fenoevo Efitia, the soil is yellowish to reddish in color. Being cohesive but not very impermeable, it is a type of acid soil on gneiss with a massive structure and whose texture is loamy-sandy. From Fenoefo Efitia to Ranomafana, this same type of soil has been eroded to give rise to little evolved lithosol and sometimes even limestone shell. And in Bevoay, always this same type of soil tends to turn red because the texture becomes silty-clayey.

Geological formation: The entire area is underlain by metamorphic terrain dominated by Fort-Dauphin gneiss, leucogranite, and charnockite. The Fort-Dauphin gneiss is of the homogeneous garnetiferous quartzo-feldspathic gneiss type with the presence of cordierite and spinel. Leucogranite is a granitic rock devoid of dark minerals (micas and amphiboles). Charnockite is a metamorphic rock that is very close to granite, except that biotite is replaced by orthopyroxene.

2.2 Current situation

At present, agricultural production is a particular asset for the 12 Communes served by this road and could bring additional income for improved livelihoods to the population if any surplus production can be marketed. However, the current state of the road linking these twelve Communes is a handicap for market access as well as access to basic services and hence local development. The access to basic services is required to strengthen the adaptive capacity of communities and reduce their vulnerability to climate shocks.

In its current state the surface of the roadway shows significant degradation; this is mainly manifested by longitudinal gullies. The gullies deepen with heavy rainfall events. The current state of the road isolates communities for part of the year e.g. following heavy rains, increases

the travel times on the roads and the wear and tear of the few vehicles that venture on the roads.

2.3 Proposed solutions

The rehabilitation of the rural road has been prioritised to improve the accessibility to basic services and opportunities for the economic development of these Communes through agricultural market access. The rehabilitation works are conditional on good management and maintenance by the AUP to ensure its sustainability. The AUP is a permanent structure for the management and maintenance of the rural roads located at the level of the Communes/association of Communes (intercommunality) and the Anosy Region.

The surface works will essentially consist of the rehabilitation of the roadbed through light and heavy reprofiling works, and contribution of selected materials (Macadam, MS). The rehabilitation of the roadway include re-profiling and the creation of longitudinal drainage works; the creation of culvert-type balance structures at low flood points, seasonal watercourse crossings; the purging of the sloughs and the installation of embankments on the clayey places, to the right of the box culverts, and for the levels of roadways to be raised; the creation of longitudinal drainage works along the track, in order to evacuate the water towards the discharge works or towards other places; the creation of crossing structures (submersible aprons) at the flood crossing point; rehabilitation and/or reinforcement of existing structures in a state of disrepair (apron, culvert, masonry ditch); the creation of drainage works on clayey places; the reopening and/or creation of crest ditches to divert runoff water from the slopes adjoining the roadway.

For the rehabilitation works the recommendations are to:

- Implement Macadam as a wearing course on very vulnerable areas and the parts often flooded. It is advisable to make sure that the Macadam is well butted;
- Implement BCR surfaces on slopes greater than 10% at least on the tread;
- Take adequate measures or solutions for the quagmires, it will be better to purge the layer of clay and/or peat (1.50m) and replace with loose material.

The earthworks concern:

- weeding and clearing of the right-of-way of the route;
- pruning shrubs and tree branches;
- light or heavy reprofiling (excavation) to correct the geometric shape of the road surface;
- purging and backfilling (raising) of flood-prone areas or sloughs.

Drainage works:

- reopening and/or creation of lateral and divergent ditches consolidated by fascinations (slope 6%);
- creation of drains to evacuate the water coming from the capillary rise;
- installation of stilling basins, gabions or riprap at the outlet of the scuppers (downstream side) is very important to mitigate the effect of erosion;
- reopening and/or creation of crest ditches to divert runoff water from the slopes adjoining the roadway.

Ditches:

- Lateral in earth and will be of triangular profile of 1,00 m x 0,40 m with fascines;
- Masonry with square profile of 0.40 m x 0.40 m or 0.50 m x 0.50 m, filled with mortar dosed at 300 kg/m3;
- Earthen ridge and will be of trapezoidal profile of 0,60 m x 0,40 m x 0,40 m with benches.

Outfalls/Swales:
Installed at useful distances for the evacuation of runoff water.
Scuppers:

- Various dimensions according to the results of the hydraulic studies and the flows.
    - D1 : 0,80 m x 0,80 m;
    - D2 : 1,00 m x 1,00 m;

Mortar dosed at 300 kg/m3 and concrete dosed at 350 kg/m3.

Roadway: Restoration of the pavement by light or heavy reprofiling according to the standard profile on certain sections. Blowing out existing messy, warped or missing cobblestone pavements. Filling, reshaping and closing with MS of existing macadam pavements. Protection of the existing macadam pavement with chains. Rehabilitation of existing concrete pavements and treads with RCC concreting of adequate thickness. The installation of wearing course in selected materials (MS) according to the characteristics of the ground of the platform. The installation of macadam pavement on the ascents and descents as well as on areas likely to be flooded. The installation of concrete pavement RCC on certain sections of large slopes.
Other works:

- creation of crossing structures by apron on very violent water crossings in the rainy season;
- rehabilitation of existing culverts and installation of new type D1 or D2 culverts;
- reinforcement of structures with RC walls, rubble masonry or other systems;
- installation of transition slabs at the entrance and exit of engineering structures (aprons).

Pavement protection works concern:

- vegetating of the embankments of the dykes;
- construction of low walls and retaining walls in rubble masonry;
- installation of chains in RC as mounding of the nailings of the Macadam;
- reduction of erosion at the level of the existing lavaka;
- installation of gabions for support.

2.4 Estimated total costs

Project cost Section I RIP 118 Soanierana PK 0+00 - Fenoevo PK 49+000 (Ar iary)	Number of population served	Cost per capita (Ariary)	Cost per Km (Ariary)
7 401 095 218,27 Ar	117 363	63 061,57	151 042,76

Sub-project cost in USD: 1 683 346.80

3. Rural road connecting RN12A to IARA plateau, District of Vangaindrano, Region of Atsimo Atsinanana

3.1 Location

The route crosses three major landscape types, from east to west, in the RN12A area to the IARA plateau:

- A coastal area of plains, alternated with low hills, extending over a width of about 50 km from the origin of the road, with an altitude varying between 0 and 50 m;
- An area of medium-sized hills with fairly wide valleys, about 50 km wide, with a varying altitude between 50 and 110 m;
- A forested area, about 100 km wide and with altitudes of 150 at more than 300 m, marked by steep slopes and fairly narrow valleys.

Climate: Like the entire south-eastern part of Madagascar, the project area has a hot and humid climate. It is frequently affected by cyclones and natural disasters such as floods. The average temperature is about 22°C during the year, with variations. The temperature is moderate depending on the season. It is generally higher than 25°C during the austral summer (from November to April) and around 20°C during the austral winter (from May to October). The moisture in this project area is primarily the result of heavy rainfall that characterize the entire east coast of Madagascar, in a general way, under the influence of the anticyclone of the Southeast of the Indian Ocean. Rainfall decreases as one moves away from the coast. The coastal areas, which extend over the districts of Farafangana and Vangaindrano and contain the project area, are very humid.

Pedology: As in the whole area, the soil is marked by the predominance of a ferralitic soil, but the final texture of the soils varies according to the relief and other geographical characteristics. Thus, alluvial soils, ferrous soils or hydromorphic soils are found. The ferralitic soils, covered with humus, are very rich and are omnipresent in the forested areas to the west. They are very fragile and only suitable for punctuated exploitation. The soils of the middle hills are also ferralitic but composed of eroded and degraded minerals. They are not very fertile and require the use of fertilizers in order to be more suitable for cultivation. Along the rivers and in the valleys, alluvial, clay and sandy soils are found. These soils called "baiboho" which are often rich in alluvial deposits, lend themselves to different types of crops, notably rice cultivation. In the lowlands (swampy areas), hydromorphic soils, often saturated with water and characterized by iron deposits, are generally encountered, making them unfavorable for cultivation.

Geology: The geology of this area is mainly made up of three large geological units, in a "submeridian" band of increasing width. Going from the coast to the highlands:

- A sedimentary terrain with a width of about 500 m to 5 km and low altitude
- Volcanic flows with a width of 20 to 40 km and medium altitude.

3.2 Current situation

The practicability of such a road must be ensured in all seasons, by the installation of adequate works of crossing of the rivers and stabilisation of hotspots in order to preserve possible cuts due to the degradations of the road connecting the communes of Soamanova, Vohitrambo, Anilobe and Iara. Indeed, this road axis constitutes, for the above-mentioned communes, an

essential link of the agricultural development of the socio-economic life of their region. Agriculture is the main source of livelihoods for the communes in this region.


In order to improve the connectivity of the communes, it is noted that the crossing and drainage works are the key elements of this road rehabilitation. The sites of these works being, most often, the points of passage presenting bottlenecks for the good functioning of the road, they are also dependent on the good execution and especially on a preliminary study of quality. Indeed, runoff water is one of the main consequences of the problems of degradation of rural roads. These degradations are major when the road crosses waterways and rainwater runoff particularly during heavy rainfall events.


The project is located in an area where the lack of credible transportation infrastructure is a limiting factor in the development of the agricultural potential of the area covered by the road. The state of the network, which is essentially made up of dirt roads that are not passable during the rainy season, reduces the mobility of people and products, which affects the productivity of the agricultural season. These dysfunctions and degradations are due to insufficiencies at the level of the network of drainage of the road. Notably all along the sections of numerous low points in the absence of works there is a risk of overflowing the hydraulic works is frequent particularly in areas that are in a state of advanced degradation. This feasibility study is therefore a decision-making tool applying technical and environmental analysis to improve the drainage system in order to increase the level of protection of the road against run-off water.

3.3 Proposed solutions

The most suitable solution is the installation of drainage and crossing structures, namely submersible structures, culverts and gutters as well as lined ditches. The road shows a

thorough degradation due to an insufficiency of the above-mentioned works making it impassable in rainy season in some points and a difficult runoff due to the insufficiency of water evacuation structures as well as the almost permanent presence of vegetation all along the road. To solve this situation, the feasibility study recommends the improvement of the level of protection of the road and to reinforce the drainage system.

According to the current state of the runway and the crossing structures, the work to be carried out is:

Earthwork

- Weeding and clearing: 15,780.30 m2
- Soil stripping: 15,780.30 m2
- Heavy or light reprofiling: 39,513.00 ml
- Excavation for widening: 1,112.25 m3
- Purge: 4,856.50 m3

Construction of sanitation and landfill works

- Creation of masonry ditch: 10,597 ml
- Creation of outlets: 92 U
- Existing scupper cleaning: 3 U
- Creation of Dalot: 8 U
- Cunette: 1,364 ml

Rehabilitation of existing crossing structures:

- Routine maintenance (cleaning of the slab, clearing of brush);
- The implementation of a coating layer;
- Enlargement of the gargoyles;
- Leveling or replacement of the coating layer

Road surface rehabilitation:

- Localized repairs
- Reprofiling (light or heavy)
- Restoration of gravel stones: 8,442 m2
- Purging by removing unsuitable materials
- Contribution of selected materials: 7,552.35 m3
- Repair of nailing: 1,700 m2

3.4 Estimated total costs

The amount including taxes of the cost of the development of the rural road connecting RN12A and IARA amounts to: two thousand one hundred and fifty two million, eight hundred and thirty one thousand four hundred and twenty-five Ariary and ninety two (Ar 2,152,831,425.92), for a length of road of 41.100km, that is to say for an average cost per kilometer of: fifty two million three hundred twenty million Ariary sixty six (Ar 52380 326.66).

The rural road is divided into three sections:

- Section 1: from the beginning (KP 0+000) to the crossroads (VANGAINDRANO and IARA), at the level of the stele on the RN12A, in VOHITRAMBO.
- Section 2: from VOHITRAMBO to ANILOBE.
- Section 3: ANILOBE to IARA.

Section 1:

No. of PRICE	DESIGNATION	AMOUNT
0-	INSTALLATION AND REMOVAL FROM THE SITE	2 715 171,00
1-	TERRASSING	50 962 461,65
II-	SANITATION	322 675 691,58
III-	CHAUSSEE	186 336 067,60
IV-	CROSSING WORKS	49 995 644,89
VI-	MAINTENANCE	6 327 393,77
VII-	ENVIRONMENTAL MEASURES	3 934 000,00
TOTAL INCL. VAT		**622 946 430,49**
TMP 8		**49835714,44**
TOTAL BEFORE TAX		**573 110 716,05**

Total cost before tax in USD: 130 358.50

Section 2:

No. of PRICE	DESIGNATION	AMOUNT
0-	INSTALLATION AND REMOVAL FROM THE SITE	5 430 342,00
1-	TERRASSEMENT	15 409 295,00
II-	SANITATION	236 376 079,45
III-	CHAUSSEE	353 737 426,80
IV-	CROSSING WORKS	41 329 308,30
VI-	MAINTENANCE	4 799 631,52
VII-	ENVIRONMENTAL MEASURES	3 934 000,00
TOTAL INCL. VAT		**661 016 083,07**
TMP 8		**52881286,65**
TOTAL BEFORE TAX		**608 134 796,42**

Total cost before tax in USD: 138 552.46

Section 3:

No. of PRICE	DESIGNATION	AMOUNT
0-	INSTALLATION AND REMOVAL FROM THE SITE	9 503 098,50
1-	TERRASSING	29 042 501,00
II-	SANITATION	275 748 276,16
III-	CHAUSSEE	519 634 051,20
IV-	CROSSING WORKS	23 215 812,29
VI-	MAINTENANCE	7 791 173,21
VII-	ENVIRONMENTAL MEASURES	3 934 000,00
TOTAL INCL. VAT		**868 868 912,36**
TMP 8		**69509512,99**
TOTAL BEFORE TAX		**799 359 399,37**

Total Cost before tax in USD: 181 820.53

The main issues observed on the rural roads include:
Lack of drainage system; obsolescence of drainage works; embankments covered with vegetation; no crossing structures; flagrant degradation of the road; very narrow roadways; platform material composed of very hydric silty clay; pavement materials of very poor quality; no regulatory shoulders;presence of peat loam; very degraded roadways; pavement erosion and hinge; ruts and longitudinal gully over the entire surface of the roadway and; fairly large cut slope.

II. Irrigation Schemes

A. Overview of irrigation schemes to be rehabilitated

The Table below shows an overview of the proposed irrigation schemes to be rehabilitated and developed. It also shows the main characteristics of these schemes.

The key climate proofing works and modifications will include change of electrical pumping to solar pumping; mechanical or biological watershed protection; channels in reinforced concrete or rubble masonry; ridge ditches; reinforced concrete overpass; reinforced concrete reservoir foundation; reinforced concrete retaining walls; improving on-farm water storage.

Region	District	Municipality	Irrigation scheme	Works	Area (ha)	Water Source	Estimated Costs ($)
Ihorombe	Ihosy	Sakalalina	Antaniheta	Rehabilitation	140	Surface Water, by gravity (Bypass reservoir)	331 800,00
Amoron'i Mania	Ambatofinandrahana	Ambondromisotra	Tsiefa	Rehabilitation	80		189 600,00
Amoron'i Mania	Ambatofinandrahana	Ambondromisotra	Sahafohy	Rehabilitation	200		474 000,00
Haute Matsiatra	Ambalavao	Iarintsena	ANDRAIKIRO	Rehabilitation	950		2 251 500,00
Ihorombe	Ihosy	Ilakakabe	Ilakakabe	Rehabilitation	980		2 322 600,00
Ihorombe	Ihosy	Sakalalina	Mahatsinjorano (Angodogondo)	Rehabilitation	630		1 493 100,00
Ihorombe	Ihosy	Ambatolahy	Andranotakatra	Rehabilitation	333		789 210,00
Amoron'i Mania	Fandriana	Sahamadio Fisakana	Befaka	Rehabilitation	400		948 000,00
Haute Matsiatra	Vohibato	Ihazoara	Antanifotsy	Rehabilitation	630		1 493 100,00
Haute Matsiatra	Ambalavao	Besoa	Angodongodona Ambony	Rehabilitation	350		829 500,00
Haute Matsiatra	Ikalamavony	Ambatomainty	Maintsobato Ambony	Rehabilitation	510		1 208 700,00
Haute Matsiatra	Ambalavao	Volamena	Rereservoirreservoirpy-Vinany	Rehabilitation	260		616 200,00
Amoron'i Mania	Ambositra	Sahatsiho Ambohimanjaka	Ankatsaoka	Rehabilitation	230		545 100,00
Atsimo Atsinanana	Farafangana	Evato	Vahadrakaka	Rehabilitation	300	Surface Water, by	711 000,00

						solar Pump	
Vatovavy	Mananjary	Antaretra	Ambodivandrika	Rehabilitation	65	Surface Water, by gravity (Bypass reservoir)	154 050,00
Vatovavy	Ifanadiana	Ifanadiana	Avanja	Rehabilitation	60		142 200,00
Vatovavy	Ifanadiana	Ifanadiana	Mandrivany	Rehabilitation	43		101 910,00
Vatovavy	Mananjary	Tsarahafatra	Belohalika	Rehabilitation	100		237 000,00
Fitovinagny	Vohipeno	Vohitrindry	Masiry	Rehabilitation	213	Surface Water, by solar Pump	504 810,00
Atsimo Atsinanana	Farafangana	Evato	Mahazoarivo	Rehabilitation	363		860 310,00
Atsimo Atsinanana	Farafangana	Tangainony	Marohaka	Rehabilitation	659		1 561 830,00
Atsimo Atsinanana	Farafangana	Mahabo menanivo	Vapaky Mahety	Rehabilitation	60		142 200,00
Vatovavy	Nosivarika	PI Fanivelona	PI Fanivelona	Rehabilitation	850		2 014 500,00
Fitovinagny	Manakara	Amboanjo	Savindrano	Rehabilitation	150	Surface Water, by solar Pump	355 500,00
Fitovinagny	Manakara	Marofarihy	Ivakoana, Mangarivotra, Tsinjoezaka	Rehabilitation	1250		2 962 500,00
Fitovinagny	Manakara	Amboanjo	Antanatanana	Rehabilitation	100		237 000,00
Atsimo Atsinanana	Farafangana	Mahavelo	Andrafia	Rehabilitation	260		616 200,00
Atsimo Atsinanana	Vangaindrano	Iara	Iara	Rehabilitation	212	Surface Water, by gravity (Bypass reservoir)	502 440,00
Atsimo Atsinanana	Farafangana	Evato	Emena	Rehabilitation	244	Surface Water, by solar Pump	578 280,00
Atsimo Atsinanana	Farafangana	Ivandrika	Bekaraoka	Rehabilitation	250		592 500,00
Atsimo Atsinanana	Farafangana	Ivandrika	Mahavelo	Rehabilitation	200		474 000,00
Atsimo Atsinanana	Farafangana	Mahafasa	Behofoky	Rehabilitation	200		474 000,00
Fitovinagny	Manakara	Mitanty	Iaban'i Gagaky	Rehabilitation	250		592 500,00
Rehabilitation works					**11 522**		**27 307 140,00**
Ihorombe	Ihosy	Satrokala	Anakondro	Nouvel aménagement	403	Surface Water, by gravity (Bypass Reservoir)	1 317 810,00
Haute Matsiatra	Ambalavao	Volamena	Ambinanimbaza	Nouvel aménagement	330		1 079 100,00

Haute Matsiatra	Ambalavao	Ambinaniroa	Andreamitily	Nouvel aménagement	400		1 308 000,00
Haute Matsiatra	Ikalamavony	Ikalamavony	LAZARIVO	Nouvel aménagement	515		1 684 050,00
Haute Matsiatra	Ikalamavony	Ikalamavony	BESADIA	Nouvel aménagement	256		837 120,00
Ihorombe	IHOSY	Mahasoa	Mikaiky	Nouvel aménagement	286		935 220,00
Ihorombe	Ihosy	Ranohira	Andreatomily	Nouvel aménagement	223		729 210,00
Haute Matsiatra	Ikalamavony	Ikalamavony	BEKOFAFA	Nouvel aménagement	270		882 900,00
Haute Matsiatra	Ikalamavony	Ikalamavony	MATSIATRA	Nouvel aménagement	450		1 471 500,00
Amoron'i Mania	Ambatofinandrahana	Soavina	Ambatomita	Nouvel aménagement	600		1 962 000,00
Amoron'i Mania	Ambositra	Ihadilanana	Ampitsinjovamborona	Nouvel aménagement	500		1 635 000,00
Ihorombe	Iakora	Volambita	Vatovihy	Nouvel aménagement	400		1 308 000,00
Ihorombe	Iakora	Ranotsara Nord	Mandabe	Nouvel aménagement	400		1 308 000,00
Ihorombe	Ihosy	Sakalalina	Andakana	Nouvel aménagement	228		745 560,00
Ihorombe	Iakora	Andranombao	Antondabe	Nouvel aménagement	350		1 144 500,00
Haute Matsiatra	Ikalamavony	Solila	Kirano-Fitemahalaitse	Nouvel aménagement	180		588 600,00
Haute Matsiatra	Ikalamavony	Solila	Androtsanakanga	Nouvel aménagement	150		490 500,00
Vatovavy	Mananjary	Ankatafana	Ambaro	Nouvel aménagement	280	Surface Water, by solar pump	915 600,00
Vatovavy	Mananjary	Ambohitsara Est	Ambohitsara Est	Nouvel aménagement	500		1 635 000,00

Atsimo Atsinanana	Farafangana	Anosivelo-Anosy Tsararafa-Vohilava	Mandatsa-Anosivelo-Sahafoza	Nouvel aménagement	345		1 128 150,00
	Farafangana	Ivandrika	Vapaky	Nouvel aménagement	500		1 635 000,00
Fitovinagny	Vohipeno	Vohitrindry	Manandria	Nouvel aménagement	100	Surface Water, by gravity (Bypass Reservoir)	327 000,00
Vatovavy	Mananjary	Ambohinihaonana	Ankalaitra	Nouvel aménagement	150		490 500,00
	Farafangana	Mahafasa	Enitravy	Nouvel aménagement	200	Surface Water, by gravity (storage reservoir)	654 000,00
Fitovinagny	Vohipeno	Ilakatra	Ilakatra	Nouvel aménagement	300	Surface Water, by gravity (Bypass Reservoir)	981 000,00
Fitovinagny	Vohipeno	Onjatsy	Onjatsy	Nouvel aménagement	500	Surface Water, by solar pump	1 635 000,00
Fitovinagny	Vohipeno	Ankarimbary	Empaly - Nakasy	Nouvel aménagement	350	Surface Water, by solar pump	1 144 500,00
Fitovinagny	Manakara	Ambahive/Ambalaroka/Vatana	Sahihy-Kirikitsa	Nouvel aménagement	400	Surface Water, by gravity (Bypass Reservoir)	1 308 000,00
New landscaping works					**9 566**		**31 280 820,00**

B. Details of some analysis done on selected irrigation schemes

1. Irrigated area of Besadia, Commune of Ikalamavony, District of Ikalamavony, Region of Haute Matsiatra

1.1 Location

The irrigation scheme (Ambalamarina Bekily village, Fokontany Ambodivohitra) is located 12 km from the city of Ikalamavony, its main town of the Commune and District, oriented North. The main activities of the population are generally devoted to agriculture and livestock.

The perimeter of Besadia is divided into three blocks (plain rice fields of 15 ha, valley rice fields of 3 ha, and rice terrace of 238 ha). Irrigable area is estimated at 256 ha, of which the current development is limited to 77 ha. An extension was considered by the users after the implementation of the program, and the irrigation of all the plots will be controlled there. The existing network belongs to the State (Commune) and is consists of a direct front type river water intake, protected by an embankment covered with vegetation for the irrigation of the perimeter of Besadia. The main canal, which circulates there dominates the entire area to irrigate and from it branches off the secondary canals which themselves feed the tertiary canals.

Only 30% of the perimeter is cultivated in the rainy season (vary aloha), area estimated at 77 ha (out of the existing 256 ha). The extension is still possible and conceivable by users. Ninety percent of Beneficiaries are owners of the land (direct exploitation regime), and 10% are tenants (system of exploitation to assert indirect in the form of sharecropper or rent paid in kind in share of harvest). For the land tenure situation, the land is of a state nature, generally without legal certificate or legal paper (title, terminal) but enjoyment of ownership recognized by the residents who are heritages inherited from generation to generation. The operators of the perimeter do not currently encounter any major land problem. Nevertheless, most of them do not have legal papers to justify their ownership land. The boundaries of the plots are commonly known to each other by the Beneficiaries and the owners.

Relief: The Municipality of Ikalamavony is surrounded by a mountain range forming a basin, which covers the different plains of the Commune. The plains of Ikalamavony on the southern part bordering the chains of Betaimboraka, that of Maromiandra extending from Ambahibe to the river Mananantanana, and the riparian plains of the Matsiatra river from Ambatovory to Bekofafa. The low relief culminates at Vavahova at 1867m and at Tsitongambalala at 1200m. The elevation of the locality of Ambalamarina Bekily is 795 m.

Geology: The rock types encountered are sedimentary rocks with granitic intercalations.
The nature of the soils is of the ferralitic type with good permeability. For pedology, in general the soil is lateritic in nature, but it is clayey silt in nature.

Hydrology: Most of the rivers have their source to the east of the Commune of Ikalamavony at the foot of the Hills. These are the Manorikandro River, Sambalahy, Sahatay, and Sariho which flow in the Ionarivo before joining the Matsiatra river. The region is characterized by the presence of very important basins of the Matsiatra river (in the North- West 18 km from the town of Ikalamavony), and Mananantanana (to the South 50 km), and by the violent cyclonic precipitation. Abundant and intense rainfall generates major floods.

Climate: The climate is almost temperate tropical mountain type with two distinct seasons- cold and dry from April to October; hot and humid from November to March. The average temperature is 22°C with a minimum of 12.4°C in July, and a maximum of 30.0°C in October. The average annual rainfall varies from 0.5 mm to 300.6 mm East winds dominate in all seasons with speeds varying from 15 to 18 knots.

1.2 Current situation

The existing problems of the irrigated perimeter can be summarized in five main points:

- The current hydro-agricultural network since 2008 does not allow the population of the site to irrigate the perimeter properly because of the water intakes, considered illegal in the vicinity of the Besadia water intake, carried out by the users upstream; and also, by the existence of multiple leaks/water losses in certain places of the canal route which are the origin of the insufficiencies in water downstream of the perimeter;
- Inadequate hydro-agricultural infrastructure and poorly maintained networks (lack of robust structures, main earthen channel of irregular section with slightly steep slopes, overgrown with brush at some points, and silted up/loaded with solid deposits or sediments);
- Degraded watershed; low water flows of the Ionarivo River; risk of strong river floods; existence/presence of rice fields/crops upstream and around the location of the Besadia water intake over time, which causes significant water losses; non-control of water by users; lack of water, which pushes farmers to change their livelihood options and choices;
- The protection/rehabilitation of the network requires means that are no longer within the reach of the users;
- Traffic within the project area difficult for the evacuation of products, for the operation and maintenance of the canals and for the connectivity of the villages affected by the development between them.

The rural populations are therefore exposed to problems of irrigation of their perimeters. However, they have a strong agricultural potential, with the availability of vast rice fields (irrigated perimeters), and this is the reason why the investment in this project formulated by the association Besadia Tsimialonjafy has been prioritised.

The results of the calculations by the CROPWAT software by choosing clay soil (black clay soil), Rice/ vegetable (market gardening)/ dry beans (beans)/ onions and the start date of transplanting automatically gives the irrigation needs in millimeter per decade: and allows the evaluation of the water needs of cultivated plants. Efficiency overall for rice is 64% and taken as 70% which is the product of irrigation efficiency of 80% with the expected distribution efficiency of 80%; and we kept this value for other cultures (market gardening/beans/onions).

The needs to be met during the dry period are around 14,470 m3/ha if the users practice rice growing / 5,970 m3/ha for market gardening / 9,147 m3/ha for onion / and 6,600 m3/ha for the bean. For the peak flow, the largest value found in the calculations is 2.96 l/s for rice cultivation which is in the month of May / 1.06 l/s for market gardening which is in the of month of August / of 1.19 l/s for beans which is in the month of August / and of 1.22 l/s for the onion which is in decade 2 of the month of September. For further calculations, we have retained the value of 2.96 l/s, i.e., based by rice cultivation as using the larger results is necessary to better ensure the sizing of the various irrigation structures for the good circulation of water, and an undersized network may lead to acute conflicts in the within the perimeter.

1.3 Proposed solutions

The hydro-agricultural network and intra-perimeter tracks to be rehabilitated have been visited with the beneficiaries and a direct consultation with them has been carried out for the consideration of their request and their knowledge of the field. The degradations or deficiencies and the existing realities have been noted. In order to reach the desired objectives, two scenarios were proposed for the improvements to be made in order to restore the network and for putting at the disposal of all the population good infrastructure in the best conditions. Scenario 1 concerns the reinforcement of the embankment covered with the water intake by a structure longitudinal rubble masonry, and rehabilitation of distribution networks and scenario 2 by reinforcing

the embankment covered with the water intake by a structure longitudinal reinforced concrete, and rehabilitation of distribution networks. For economic reasons the least expensive of the scenarios was selected to be cost effective. The outlined works are as follows:

- Installation of protective linings (masonry, concrete) on the delicate places (at the level of the Besadia intake, the dead head and the primary canal); installation, at the level of the Besadia intake, of a low longitudinal structure of lower level than the average water level for the creation of the lateral cells clogging little by little, and also in order to avoid the illegal actions of the users upstream;
- Development of the main canal N°01 (cleaning and regrading of 2295 ml of the existing one; reinforcement of bank in embankment of 67 ml; installation of a new canal of 4220 ml on soft ground and 1573 ml on rocky ground; derotation of 08 ml); and of the main canal N°02 (cleaning and regrading of 352 ml of the existing one);
- Installation of new ancillary works on the main canal N°1 (06 sections of concrete canal of 1,443 ml total length having respectively 336.50, 987.5, 25, 08, 35, 37ml, and 14 ml length; 05 gutters; 01 watering place; 02 overpasses; 09 zebu crossings; 14 crosswalks; 76 secondary intakes; 04 tarpaulins; low wall of 20 ml length); on the main canal N°2 (06 secondary intakes); Intra-perimeter track repairs;

The participation of the Beneficiaries of the network with respect to their contribution to be brought within the framework of the project (approximately 5% of the cost of development: manual work on the secondary canals of a length of 350 m and track of a length of 5720 m with the biological protection); their sensitization for the maintenance of the infrastructures; and their close collaboration with the decentralized authorities (Communes, District). Collaboration with the beneficiaries and authorities is necessary because "the success depends on communication and their participation and engagement".

Specific works

The facilities proposed for the rehabilitation of the perimeter are below:

Beneficiary contributions

- Manual works on the secondary canals with a length of 350 ml (clearing, digging of canals);
- The development of two intra-perimeter tracks of 1.99 km and 3.73 km in length (Weeding and/or clearing on certain parts; Light reprofiling and backfilling for a few servings; and Creation of earthen ditches all along the descents or climbs).
- Biological protection for environmental measures (planting of hedgerows at PM 1673, 1800, 1900, 2415, 5750; and reforestation at PM 1900, 2415, 5750)

Works by the Contractor

- Rehabilitation of the BESADIA water intake:
- The construction of the protective wall of the right bank of the Ionarivo river in masonry rubble stones 80 m long, 1.50 m high, and 50 cm thick on site furniture.
- The creation of AVANT CANAL composed of:
- The construction of a concrete channel with a length of 329 ml;
- The construction of a 3 lm tarpaulin at PM 292 measuring 3.00 x 0.30 x 0.40m (Canal crossing the front canal);
- The construction of a recharge structure at PM 376.50+7 (Sakasaka Ankodivana);
- The construction of a splitter with two outputs at PM 396.50 for main channel N°1 and N°2 equipped with two (02) screw valves measuring 60 x 60 cm and 40 x 40 cm.

The creation of a main canal N° 1:

- The construction of a concrete channel with a length of 1100.50 ml: from 987.50 ml to PM 396.50, from 25 ml at PM 1673.50, 8 ml at PM 1790, 35 ml at PM 1871, 37 ml at PM 3978 (on soft ground); 6 ml at PM 2079, 2 ml at PM 2141, and 14 ml at PM 7528 (on rocky terrain).
- The construction of five (5) scuppers 4m wide at PM 6912, 7317, 7979, 8789, 9356.
- The construction of a drinking trough at PM 885.
- The construction of nine (9) zebu crossings at PM 1085, 1610, 2847, 3293, 4364, 4830, 5340, 6078, 6350.
- The construction of seventy-six (76) secondary intakes equipped with pull valves padlocked 20 x 20 cm at PM 500, 600, 700, 800, 950, 1029, 1085, 1240, 1384, 1438, 1550, 1591, 1673,50, 1755, 1970, 2065, 2079, 2168, 2246, 2281, 2317, 2365, 2498, 2545, 2598, 2657, 2752, 2847, 2918, 3061, 3159, 3223, 3343, 3408, 3504, 3609, 3648, 3679, 3686, 3891, 3903, 4001, 4062, 4179, 4217, 4333, 4430, 4500, 4557, 4650, 4900, 5500, 6475, 6650, 6800, 7250, 7400, 7700, 7850, 7950, 8050, 8200, 8350, 8450, 8550, 8700, 8800, 8950, 9100, 9150, 9300, 9650, 9850, 9850, 10050, 10250.
- The construction of three (3) tarpaulins 6 m long at PM 4850, PM 5050, PM 5414.
- The construction of one (1) 17 m long tarpaulin at PM 7528, PM 8454.
- The construction of a low wall with a 20 ml long apron at PM 2430.
- Regabaritage and canal cleaning of length 2311.50 ml.
- Bank reinforcement (backfill) 67 ml long.
- Canal digging in soft ground with a length of 4171 ml.
- Canal digging in rocky terrain with a length of 1573 ml.
- Rock removal of 6ml at PM 2079, and 2ml at PM 2141.

Construction of a main canal N° 2:

- Regabaritage and canal cleaning of length of 352 ml.
- Construction of six (6) secondary sockets at PM 396.50+101, 396.50+130 396.50+182, 396.50+241, 396.50+287, 396.50+352

1.4 Estimated total costs[1]

Perimeter	Irrigable area in Ha	Cost of the works including VAT of the selected scenario (Ar.)	Estimated program costs (Ar.)	Cost per hectare (Ar. /ha)
Besadia	256	1 391 221 975,04	1 391 221 975,04	5 434 460,84

Cost in USD: 316,444.28

DESIGNATIONS	Amounts (Ar.)
GLOBAL TOTAL WORK	1 162 617 954,04
TOTAL BENEFICIARY CONTRIBUTIONS	58 501 000,00
TOTAL PROJECT COST	1 221 118 954,04

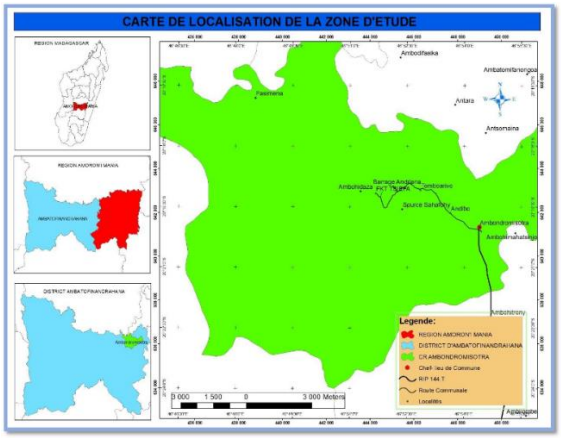
Cost in USD: 277,753

[1] As of 15th May 2023, UN official exchange rate is 1 USD = 4,396.42 MGA

2. Irrigated area of Tsiefa, Commune of Ambondromisotra, District of Ambatofinandrahana, Region of Amoron'imania

2.1 Location

The perimeter of the Tsiefa-Andriana cluster is located in the Fokontany of Tsiefa, Rural Commune of Ambondromisotra, District of AMBATOFINANDRAHANA, Region AMORON'I MANIA. The site of the water source (reservoir) is located at 7 km from the main town of the Commune and at 500 m from the main town of the Fokontany and is accessible by 4x4 car, by motorcycle during all the year.



Relief: The watershed of Tsiefa is characterized by the acuteness of the silting phenomenon. The presence in this area of an island of anatexite granite which is a coarse-grained metamorphic rock of feldspar can explain this phenomenon. Indeed, the weathering of this rock not only produces laterite more resistant to erosion but also very friable sandy kaolin. The laterite covers only the superficial part, the sandy kaolin constitutes a thick layer in layer in depth. Once this layer is reached, the erosion process accelerates rapidly. At the least contact with water, the fine-textured kaolin goes into solution, only a sand aggregate remains which is gradually sacrificed and transported by runoff and this phenomenon leads to silting up of the Andranobe resevoir in Tsiefa The loads of solid matter then settle in meanders or other places conducive to sedimentation.

As for the relief, the mountain ranges (Ambatovaventy, Andrangaly, Vohimavo and Mandrorosy) which around the Commune give it the shape of a wide basin which occupies almost half of the territory whose altitude varies between 1000 m and 1300m. They are very uneven with slopes ranging from 15% to 35%.

Soils: Tanety soils are generally fairly rocky red and yellow red ferralitic soils on the sides and ridges of the hills. Those in the lowlands have a very fertile alluvial sand texture which lends itself well to the flooded rice field especially after a good amendment. Soil erosion is a particularly destructive phenomenon in Madagascar, which is reflected by the formation of lavaka (huge holes ripping open the hills) whose causes would be the aggressiveness climate change, overgrazing, bush fires and deforestation. Two lavaka formations are found in the watershed upstream of the Tsiefa resevoir; Ankadimbehivavy and Tanananomby. Indeed, the sandy deposits from these two formations deposit in the meander of Ampasina before breaking into the bed of the Andranobe downstream. Measures to mitigate these environmental problems, will include reforestation and planting young soil-fixing plants such as vetivers in the zone sensitive to erosion and lavaka training.

Climate: Of the tropical altitude type, the climate of Ambondromisotra is characterized by two main seasons well distinct: A rainy season from October to April with an average dry temperature of 28°C and another relatively dry and cold which can reach 16°C to 18°C which goes from May in the month of September. Being able to reach 1200mm to 1600mm the annual rainfall is distributed as; 85%-90% from October to April

peaking at 300mm per month in middle of the season (December - January). A dry season which extends over the remaining five months from May to September during which it falls monthly less than 40mm.

Hydrographic network: The Commune is crossed from East to West by the Mania River and its two tributaries of Tsindra and Andranobe. A multitude of small rivers and streams also pass through the Municipality: Saharambazina, Andranobe, Anotsy, Ifeta, horoka and Andranotakatra in Fokontany by Tsiefa.

2.2 Current situation

The first development of the Tsiefa irrigation perimeter was initiated by the State microhydraulic project in 1980. According to the field survey, no rehabilitation or renovation work has been carried out by other projects on the Tsiefa irrigation network, but improvement work has been initiated by the members of the Water Users' Association, such as the reconstruction of the low wall canal made of rubble stone. The irrigated microperimeter of Tsiefa has a diversion weir built in cyclopean concrete, works on the main canal such as a low wall, a framework gutter, etc. The body of the resevoir is in average condition, but the silting up of the upstream section poses major problems for the entire irrigated perimeter. Because of the silting upstream and the non-existence of the gate at the main intake, the cleaning of the canal is a major issue for the beneficiaries during the irrigation period. It was also noted that the part of the weir next to the flush gate on the left bank was ravaged by the flood; the foundation of the anchor wall on the right bank is scoured. In addition, according to the beneficiaries, during the field investigation, the part of the front canal of about 34 ml was ravaged by the rain and the landslide of the foundation. Indeed, the beneficiary members have diverted the canal by building a low wall of rubble stone.

As for the Andriana perimeter, the first development was initiated by the beneficiaries in 2005. The resevoir was ravaged by the flood after a few years of existence. In fact, the beneficiaries of this perimeter built a temporary structure made of grass and sandbags reinforced with logs. Each year and at each passage of rainy event, this temporary structure needed rehabilitation. In addition, poor water management, the use of wild catch by all, are factors that compromise the total exploitation of the perimeter.

2.3 Proposed solutions

The main options to be considered for the development concern the following aspects: the choice of the route of the canal, the type of works to be implemented. Regarding the choice of the route of the channel, the analysis of the options is based on the reasons following:

It is preferable to keep the current route of the existing channel, because it is lower cost given the financial volume; To avoid the environmental problems encountered on the ground (erosion, lavakas, ravines...), we will keep the route of the existing canal as much as possible; For the sustainability of hydro-agricultural infrastructures, it is necessary to implement in a rigorous manner the new Malagasy Standards for the Construction of Hydro-agricultural infrastructure against floods and floods (NIHYCRI) for the design and sizing of hydro-agricultural works As for the type of works to be implemented, all the works to be put in place are in reinforced concrete with metal formwork according to the recommendations of the DEFIS team and the local circumstance as well as the environmental problems encountered on site (lavakas, erosion).

The rehabilitation work will aim at:

- Rehabilitating the irrigation network of the said perimeter;
- Ensuring the sustainability of the network's operation;
- Improving the service offered by this irrigation infrastructure from a technical, social and environmental point of view, while also seeking the maximum sustainability of the rehabilitated or newly established works by considering an economy and an optimization of the costs of works.

Rehabilitation works of hydro-agricultural networks and choice of alternative

Given the validation of the APS and the content of the APD, on the budgetary level, variant N°02 is more expensive compared to variant No. 01. Technically, variant No. 02 is more reasonable and can solve the problems related to the development of the perimeter. The work to be undertaken within the framework of this rehabilitation of hydro-agricultural networks in the irrigated perimeter of Tsiefa are as follows:

Upstream site: Tsiefa

- Reloading with cyclopean concrete of the downstream wall of the resevoir to have the profile prescribed by the NIHYCRI standard, covering in waterproofing veil of the body of the resevoir of thickness 10cm and metal valve equipment of two existing flushes;
- Partial demolition of the existing anchor wall, comforting works of the anchor wall against the scouring of the foundation, raising the anchor wall by 0.60m in height and laying metal valve at the main socket
- PM 00- PM 10: demolition of existing structures and reconstruction of grit trap;
- PM 10.00- PM 45.00: construction before canal in reinforced concrete low wall and concreted canal;
- PM 45.00- PM 106.00: construction of concrete channel of section 60x60 and laying of plots at MP 86.50;
- PM 164.00- PM 225.00: low wall construction in reinforced concrete 50x50;
- PM 323.00- PM 327.00: construction of zebu passage and water trough;
- PM 431.00- PM 497.20: concrete courier construction of 40x40 section;
- PM 497.20- PM 475.00: construction of dissipation basin (Connection of the canal to the old route);
- PM 515.00- PM 531.00: existing courier rehabilitation including the stilling basin;
- PM 531.00- PM 544.90: rehabilitation of low wall and existing concrete channel;
- PM 544.90- PM 584.00: construction of concrete channel and rehabilitation of the concrete channel existing;
- PM 548.00- PM 612.00: demolition of existing structures and construction of concrete cover armed;
- PM 650.00: overpass construction;
- PM 650.00- PM 697.00: low wall construction in reinforced concrete 50x50;
- PM 915.00; PM 950 and PM 1018.70: divider construction;
- PM 1668.50- PM 1708.70: construction of a low wall fitted with a spilling sill;
- Cleaning and reshaping of earth canal of variable section;
- Digging of new route of the channel of variable section;
- Installation of parcel catches;
- Environmental works.

Downstream site: Andriana
PM 0.00: gravity resevoir construction with a flush valve fitted with a metal valve;
PM 0.00 – PM 44.50: construction before canal in reinforced concrete tarpaulin extended into canal concreted with lateral safety overflow;
PM 74.50 – PM 103.30: construction of a reinforced concrete tarpaulin;
PM 304.40 – PM 347.00: Construction of courier with stilling basin;
Cleaning and reshaping earth canal of variable section.
Construction of a slab in Andranotsokina.

Adequacy of Water Resources and Needs
According to the studies of mobilized inputs, the adequacy of water resources and needs is summarized as follows:

- Inflow available: 632.3 l/s;
- Dfc: 2.16 l/s;
- Area of the perimeter to be irrigated: 80 ha;

- Nominal flow at the head: 172.87 l/s

RESULTS	Good control of water	Improved technical and managerial capacity organizational structure of the WUA
BENEFITS TO BE DERIVED FROM THE IMPLEMENTATION OF THE SUB-PROJECT	-Irrigation of 20ha of rice fields extensions -Increase of production -Opportunity to develop the SRI/SRA -Possibility of introducing new, more productive rice varieties and thus increasing yields -Possibility of strengthening the off-season crop (bean, potato)	-Expansion of the number of members of the association to increase the financial capacity -Improvement of the organizational and management capacity of the association and its activities -Possibility of extending other IGAs (income generating activities)

2.4 Estimated total costs[2]

DESIGNATION	AMOUNT
0 PREPARATORY WORK	36 771 000,00
I-BARRAGE TSIEFA	42 058 575,00
II-REHABILITATION DESSABLEUR : PM 0,00 and PM 10,00	24 511 985,00
III - PRE-CHANNEL AND CONCRETE CHANNEL ON MAIN CHANNEL	48 569 664,00
IV-CONSTRUCTION OF ZEBUS CROSSING : PM 97,00 - PM 103,00	15 644 779,00
V-CONSTRUCTION OF REINFORCED CONCRETE WALL : PM 164,00 - PM 225,00	12 893 892,00
VI-CONSTRUCTION OF ZEBUS CROSSING	4 885 000,00
VII-CONSTRUCTION OF YARD WITH DISSIPATION BASIN: PM 431.00 - PM 497.20	23 030 785,00
VIII - REHABILITATION OF THE COURTYARD, DISSIPATION BASIN, CONCRETE CHANNEL, LOW WALL AND CONSTRUCTION CONCRETE CHANNEL : PM 185 AND PM 515,00 - PM 584,00	15 278 067,00
IX- PARTIAL DEMOLITION OF EXISTING STRUCTURES AND CONSTRUCTION OF A TARPAULIN IN BA : PM 584,00 - PM 612,00	27 698 371,00
X-CONSTRUCTION OF OVERPASS : PM 650,00	15 641 156,00
XI-CONSTRUCTION LOW WALL MADE OF CONCRETE WITH ANCHOR ON ROCK : PM 650,00 - PM 697,00	29 598 070,00
XII-CONSTRUCTION PARTITEUR : PM 915,00 ; PM 950 AND PM 1018,70	13 660 669,00
XIII -CONSTRUCTION OF A LOW WALL IN REINFORCED CONCRETE ON ROCK PM 1668,50 :	10 086 563,00
XIV-CAPTURE DRAIN ANDRIANA	16 279 504,00
XV-FORWARD CHANNEL: CONCRETE CRANK AND CHANNEL - MP 0.00 to MP 44.50	27 332 490,00
XVI-CONSTRUCTION REINFORCED CONCRETE SHEETING : PM 74,50 - PM 100,30	21 499 844,00
XVII-CONSTRUCTION OF COURTYARD WITH DISSIPATION BASIN : PM 304,00 and PM 347,00	14 662 077,00
XVIII -CONSTRUCTION OF SEVENTEEN (17) PARCEL OUTLETS INCLUDING 11 OUTLETS FOR TSIEFA AND 06 OUTLETS FOR ANDRIANA	10 011 368,00
XIX- DEVELOPMENT OF THE SAHAFOHY STREAM LEFT BANK	10 600 570,00
XX-REGABITATING AND REPROFILING EARTHEN CANAL	18 483 930,00
XXI-RADIER ANDRANOTSOKINA	81 390 000,00
XXII-EARTHEN CANAL AND ENVIRONMENTAL TREATMENT	28 290 910,00
TOTAL AMOUNT	**548 879 269,00**

[2] As of 15th May 2023, UN official exchange rate is 1 USD = 4,396.42 MGA

RECAPITULATION	SELECTED ALTERNATIVE
0 PREPARATORY WORK	36 771 000,00
I-BARRAGE TSIEFA	42 058 575,00
II-REHABILITATION DESSABLEUR : PM 0,00 and PM 10,00	24 511 985,00
III - PRE-CHANNEL AND CONCRETE CHANNEL ON MAIN CHANNEL	48 569 664,00
IV-CONSTRUCTION OF ZEBUS CROSSING : PM 97,00 - PM 103,00	15 644 779,00
V-CONSTRUCTION OF REINFORCED CONCRETE WALL : PM 164,00 - PM 225,00	12 893 892,00
VI-CONSTRUCTION OF ZEBUS CROSSING	4 885 000,00
VII-CONSTRUCTION OF YARD WITH DISSIPATION BASIN: PM 431.00 - PM 497.20	23 030 785,00
VIII - REHABILITATION OF THE COURIER, DISSIPATION BASIN, CONCRETE CHANNEL, LOW WALL AND CONSTRUCTION OF CONCRETE CANAL : PM 185 AND PM 515,00 - PM 584,00	15 278 067,00
IX- PARTIAL DEMOLITION OF EXISTING STRUCTURES AND CONSTRUCTION OF A TARPAULIN IN BA : PM 584,00 - PM 612,00	27 698 371,00
X-CONSTRUCTION OVERPASS : PM 650,00	15 641 156,00
XI-CONSTRUCTION OF LOW WALL MADE OF CONCRETE WITH ANCHOR ON ROCK : PM 650,00- PM 697,00	29 598 070,00
XII-CONSTRUCTION PARTITEUR : PM 915,00 ; PM 950 AND PM 1018,70	13 660 669,00
XIII -CONSTRUCTION OF A LOW WALL IN REINFORCED CONCRETE ON ROCK PM 1668,50 :	10 086 563,00
XIV-CAPTURE DRAIN ANDRIANA	16 279 504,00
XV-FORWARD CHANNEL: CONCRETE CRANK AND CHANNEL - MP 0.00 to MP 44.50	27 332 490,00
XVI-CONSTRUCTION REINFORCED CONCRETE SHEETING : PM 74,50 - PM 100,30	21 499 844,00
XVII-CONSTRUCTION OF COURTYARD WITH DISSIPATION BASIN : PM 304,00 and PM 347,00	14 662 077,00
XVIII -CONSTRUCTION OF SEVENTEEN (17) PARCEL OUTLETS INCLUDING 11 OUTLETS FOR TSIEFA AND 06 OUTLETS FOR ANDRIANA	10 011 368,00

RECAPITULATION	SELECTED ALTERNATIVE
XIX- DEVELOPMENT OF THE SAHAFOHY STREAM LEFT BANK	10 600 570,00
XX-REGABITATING AND REPROFILING EARTHEN CANAL	18 483 930,00
XXI-RADIER ANDRANOTSOKINA	81 390 000,00
TOTAL AMOUNT	**520 588 359,00**

Cost in USD: 118,411.88

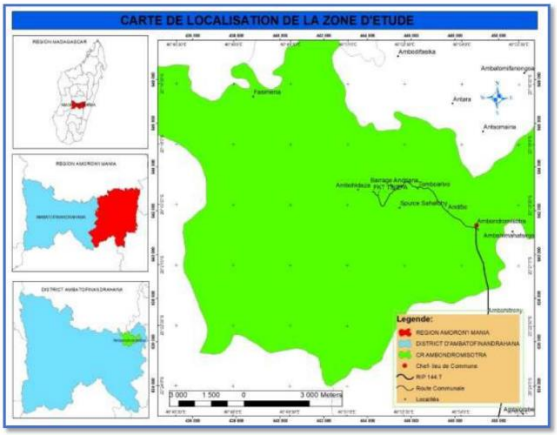
N°	DESIGNATION	U	QTE	PU	AMOUNT
113-d	Digging channel in earth 40x40	ml	541,30	19 200,00	10 392 960,00
404	Reforestation	ha	3,50	5 113 700,00	17 897 950,00
	TOTAL CONTRIBUTION OF BENEFICIARIES				**28 290 910,00**

3. Irrigated area of Ofahafohydans, Commune of Ambondromisotra, District of Ambatofinandrahana, Region of Amoron'i Mania

3.1 Location

The site of the Sahafohy spring is located in the rural commune of Ambondromisotra. This Commune is located 90 km from Ambositra by taking the National Road RN7 to PK 15 in the direction of Fianarantsoa, there is a fork in the road to the right by following the National Road RN 35 to PK 45, there is also another fork in the road to the right by taking the Public Road RIP 144.T over a distance of 30km.

Concerning the access to the catchment site, there is a communal road for a distance of 5 km from the main town of the Commune to the main town of Fonkotany and this road is accessible by 4x4 car and motorcycle during all the year: then by footpath about 20 minutes. The perimeter of Sahafohy, which is irrigated by natural springs converging from Sahafohy is situated in the two (02) Fokontany of the Rural Communes of Ambondromisotra: Tomboarivo and Mahazina. The irrigation network of the Sahafohy irrigated microperimeter is equipped with service roads inside the perimeter.



Relief: The watersheds of Sahafohy, with an area of 0.95 km2 extend on the lower flanks of the Ambatovaventy and Andrangaly mountains and form depressed areas, which are lands with agricultural vocation. Most of the watershed is covered by grassy savannas and the soil is generally fertile. However, in the hills of Ambohipeno and Vohibe located upstream of the catchment area, the geological substrate has characteristics that are very sensitive to erosion. Considering the degree of rock metamorphism in this central part of the SQD series (schisto-quartzodolomic system). It is threatened by the phenomenon of Lavakisation due to erosion, bush fires, deforestation and the practice of cultivation on the steep slope. Consequently, it can be deduced that the catchment area upstream of Sahafohy is in the process of massive degradation if nothing is done. As for the relief, the mountain ranges (Ambatovaventy, Andrangaly, Vohimavo and Mandrorosy), which around the Commune give it the shape of a fairly wide basin which occupies almost half of the territory whose altitude varies between 1000 m and 1300m. They are very uneven with slopes ranging from 15% to 35%.

Soils: Tanety soils are generally fairly rocky red and yellow, red ferralitic soils on the sides and ridges of the hills. Those in the lowlands have a very sandy-alluvial texture. Fertile land that lends itself well to flooded rice growing, especially after a good amendment. Outside of verdant plains devoted to rice cultivation, the overall vision of the area is that of a landscape bare and cracked barely covered by vegetation on the edges of the lavaka and the sides of the hillsides. The hills of Ambohipeno and Vohibe located upstream of the capture is the perfect illustration of this. Despite the efforts already made to stem the erosion phenomenon, the situation still seems unstable. Generally, soil erosion is a particularly destructive phenomenon in the highlands of Madagascar, which results in the formation of lavaka (huge holes ripping open the hills) whose causes would be the aggressiveness of the climate, overgrazing, bush fires and deforestation.

Climate: Of the tropical altitude type, the climate of Ambondromisotra is characterized by two main seasons well distinct: a rainy season from October to April with an average dry temperature of 28°C and another relatively dry and cold which can reach 16°C to 18°C which goes from May in the month of September. Being able to reach 1200mm to 1600mm the annual rainfall is distributed as; 85%-90% from October to April peaking at 300mm per month in middle of the season (December - January). A dry season which extends over the remaining five months from May to September during which it falls monthly less than 40mm.

3.2 Current situation

The irrigated microperimeter of Sahafohy is fed by natural springs converging in a natural catchment and it has structures on the main canal such as culverts, low walls, circular and frame gutters, reinforced concrete covers, metal covers, etc. The structures on the canal are rather worn out, especially the reinforced concrete structures and the rubble stone structures. The slope slide on the right bank side of the main canal is a major problem of the perimeter because after the passage of rainy events, there is a lot of cleaning and maintenance work on the degraded network. It was also noted that there are several lateral watersheds that bring sand on the channel causing silting at the level of the channel and the collapse of the banks. The degraded state of the watershed upstream of the natural catchment is an acute threat to the Sahafohy irrigation perimeter. In addition, the poor technical management of water, the use of wild catch by all, are factors that hinder the total exploitation of the perimeter.

The irrigation network of Sahafohy has hydro agricultural infrastructures. The entire network is made of:

- Natural springs converging in a natural catchment of 950 m2.
- Deadhead canal:
  - Section of about 20ml: earthen channel of variable section;
  - Section 25 ml: metallic nozzle of 50 cm diameter;
  - Section 325 ml: earthen canal of variable section;
  - Lateral discharge structure in 80 cm diameter nozzle at MP 123.80;
- Earthen channel of variable section;
- 01 low wall in rubble masonry of 5.00 m length; 0.50 m height and 0.40 m thickness;
- 01 low wall in rubble masonry of 11.60 m length; 0.40 m height and 0.40 m thickness;
- Φ 50 nozzle of 39.75 ml;
- 01 work falls;
- 01 reinforced concrete tarpaulin with two crosspieces (pile built by the initiative of the beneficiaries) of trapezoidal section B=0,75 m; b=0,50 m; h=0,75m and of 21,00m length;
- 01 gangway with a deck size of 1.00 m x 2.10 m;
- 01 mixed circular gutter with a diameter of 1,00m and a length of 8,40m;
- 01 parcel catchment work (set up by the beneficiaries);
- 01 gutter frame of 0,60x0,60;
- 01 masonry course of 0,50m x 0,35 m section;
- 02 metal tarpaulins including:

❖ Sheet n° 01 : three spans anchored on two abutments in rubble stone masonry which has a section of 0,30x0,36 and a length of 19,10m;

❖ Sheet n°02: four spans anchored on two abutments in rubble masonry whose dimensions are as follows: B=0,40m; b=0,30m; h=0,35 and L=25,30m.

Currently, it has been observed that:

- At natural springs converging in a natural catchment:

➢ Threats of silting due to the degradation of the upstream watershed;

➢ Threat of resevoir failure at the catchment due to the degradation of the bank of the side stream draining the upstream watershed;

- At MP 00- to MP 25: Φ 50 metal nozzle with head works at inlet in old condition and head works degradation at outlet;

- At MP 25: existence of progressive scouring at the exit of the nozzle;
- At MP 123.80: Collecting runoff from the side watershed into the main channel and slope slide next to the main channel;
- Slope slippage on a few places in the earthen channels;
- All the structures are in an old state, especially the reinforced concrete and rubble masonry structures;
- Presence of wooden tarpaulin which does not comply with the standard;
- Permanent leaks in two metal covers;
- Existence of channel passage on the service track at the perimeter (without structure);
- Presence of zebu crossing not in conformity with the standard and presence also of wild catch;
- Presence of non-equitable water distribution and passage of related watershed runoff along the main channel.
-

3.3 Proposed solutions

The rehabilitation work will aim at:

- Rehabilitating the irrigation network of the said perimeter;
- Ensuring the sustainability of the network's operation;
- Improving the service offered by this irrigation infrastructure from a technical, social and environmental point of view, while also seeking the maximum sustainability of the rehabilitated or newly established works by considering an economy and an optimization of the costs of works.

Irrigation Network:

- PM 0.00- PM 25.00: demolition head of existing structure, removal of existing diam 50 nozzle and construction of covered concrete channel 50x50 with upstream and downstream work head;
- PM 25.00: laying rockfill to stop scouring;
- PM 113.00- PM 125.00: construction of 80x80 concrete channel, construction of overpass and rehabilitation of the discharge structure at PM 123;
- PM 266.50- PM 271.50: construction of overpass;
- PM 350.00- PM 400.00: construction of 80x80 concrete channel covered with removable slab, and scour treatment by laying rockfill;
- PM 513.00- PM 518.00: demolition of existing low wall and reconstruction of concrete low wall armed;
- PM 616.00- PM 622.00: construction of zebu passage in 80x80 frame scupper;
- PM 736.00- PM 766.00: 80x80 concrete channel construction covered with removable slab;
- PM 804.50 - PM 809.50: overpass construction;
- PM 841.40- PM 853.00: demolition of existing low wall and reconstruction of concrete low wall armed anchored on rock;
- PM 888.60- PM 901.00: removal of nozzle Φ50 and construction of reinforced concrete tarpaulin of 50x50;
- PM 901.00- PM 967.70: low wall construction 50x50 in reinforced concrete and digging;
- PM 967.70- PM 972.70: construction of reinforced concrete dissipation basin;
- PM 1037.00- PM 1046.50: demolition of existing fall and reconstruction of fall with stilling basin;
- PM 1098.75- PM 1126.90: removal of three Φ50 nozzles and construction of a 60x60 tarpaulin in reinforced concrete;
- PM 1195.00- PM 1225.00: demolition of existing tarpaulin, removal of nozzle Φ50 and construction of 70x70 reinforced concrete tarpaulin;
- PM 1325.00 – PM 2291.00 – PM 2527.60: construction of maneuvering bridge;

- PM 1375.00- PM 1381.00: construction of zebu passage in 80x80 frame scupper;
- PM 2000.00- PM 2016.30: development of drinking trough and rehabilitation of circular scupper;
- PM 2124.00: demolition of the existing structure and construction of the divider;
- PM 2832.00- PM 2838.00: construction of zebu passage in 80x80 frame scupper;
- PM 2921.60- PM 2925.00: existing culvert rehabilitation;
- PM 3040.20- PM 3064.40: demolition of existing structures and construction of courier in 40x40 section reinforced concrete;
- PM 3145.40- PM 3173.20: removal of metal tarpaulin no. 02, demolition of existing structures and construction of 50x50 reinforced concrete tarpaulin including the hydraulic connection work;
- PM 3366.80- PM 3377.00: development of drinking trough and construction of 60x60 frame culvert;
- PM 3625.00- PM 3647.00: 50x50 concrete channel construction and frame scupper construction 50x50;
- Resurfacing and reshaping of the main channel of variable section;
- Digging some section of the earthen canal;
- Installations of twenty-three (23) plots taken: PM 417- PM 543.60- PM 654.50- PM 967.70 – PM 1037-PM 1325-PM 1375-PM 1425-PM 1662-PM 2124-PM 2250-PM 2291-PM 2346-PM 2411- PM 2441- PM 2495.00- PM 2525.60- PM 2832- PM 2855-PM 2930.30- PM 2947.50-PM 3035.80 - PM 3140.80
- Environmental works.

Access track to the perimeter

Construction of submersible apron at ground level with access ramp in Andranolava

RESULTS	Good control of water	Improved technical and managerial capacity organizational structure of the WUA
BENEFITS TO BE DERIVED FROM THE IMPLEMENTATION OF THE SUB-PROJECT	-Irrigation of 133 ha of additional rice fields -Increase of production -Opportunity to develop the SRI/SRA -Possibility of introducing new, more productive rice varieties and thus increasing yields -Possibility of strengthening the off-season crop (bean, potato)	-Expansion of the number of members of the association to increase the financial capacity -Improvement of the organizational and management capacity of the association and its activities -Possibility of extending other IGAs (income generating activities)

The Beneficiaries' Association will be responsible for the maintenance of the future structure. The protection of natural springs, the rehabilitation and reconstruction of protection works and canal works according to current standards, will ensure the delivery of water to the end of the network. This will allow the beneficiaries to:

- Apply double season rice cultivation or increase the area cultivated in the off-season, thus increasing income;
- Optimize production through good water and land management;

- Increase the area served by the source, resulting in income growth and food and nutrition security;
- Increase production yields by improving cultivation practices (SRI/SRA, PAPRIZ) and water management.
-

3.4 Estimated total costs[3]

DESIGNATION	AMOUNT
0 PREPARATORY WORK	62 847 000,00
I-REMOVAL OF NOZZLE, DEMOLITION OF EXISTING HEADWORKS AND CONSTRUCTION OF CONCRETE CHANNEL COVER 100x100	33 973 532,00
II-PLACEMENT OF RIPRAP AT PM 25.00 AND CONSTRUCTION OF OVERPASS AND REHABILITATION OF THE DUMPING STRUCTURE : PM 119,00	47 776 631,00
III -STRUCTION OF TWO (02) OVERPASSES: PM 269.00 and PM 807.00	37 550 736,00
IV-CONSTRUCTION OF CONCRETE COVERED CHANNEL AT PM 375,00 LENGTH 50,00 ml AND INSTALLATION RIPRAP PM 350 - PM 362	52 570 892,00
V-RECONSTRUCTION WALL: PM 515.00 and PM 847.00	5 843 399,00
VI-CONSTRUCTION OF THREE (03) ZEBUS PASSAGES: MP 619.00; MP 1378.00 and MP 2835.00	26 722 023,00
VII-CONSTRUCTION OF CONCRETE COVERED CHANNEL AT MP 751,00 LENGTH 30,00 ml	28 607 189,00
VIII - INSTALLATION OF BUSE Φ50 AND CONSTRUCTION OF ARM CONCRETE FRAME: 12.40 ml LENGTH	10 493 364,00
IX-CONSTRUCTION OF WALL AND FALL WITH DRAINAGE BASIN : MP 901.00 to MP 972.70	27 111 924,00
X-DEMOLITION OF EXISTING WATERFALL, RECONSTRUCTION OF WATERFALL AND DISSIPATION BASIN : PM 1037,00 -PM 1046,50	11 334 000,00
XI-DEPOSITION OF THREE NOZZLES Φ50 AND CONSTRUCTION OF ARM CONCRETE FRAME PM 1098,75 - PM 1126,90 : 28,15 ml	26 875 783,00
XII-DEMOLITION OF EXISTING STRUCTURE, REMOVAL OF NOZZLE Φ50 AND CONSTRUCTION OF REINFORCED CONCRETE COVER : 30,00 ml	32 935 200,00
XIII - REHABILITATION OF DALOT CIRCULAR : PM 2000,00 to PM 2016,30	28 470 989,00
XIV-DEMOLITION OF THE EXISTING STRUCTURE AND CONSTRUCTION OF A PARTITION AT THE PM 2124,00	9 381 912,00
XV-REHABILITATION OF GUTTER AT PM 2925,00	5 252 403,00
XVI-DEMOLITION OF EXISTING STRUCTURES AND REHABILITATION OF THE COURIER AND METAL SHEETING N°01 : PM 3040,20-PM 3090,70	79 933 074,00
XVII - REHABILITATION OF METAL COVER N°02 : PM 3145,40 -PM 3173,20	73 737 609,00
XVIII - WATERING TROUGH AND GUTTER CONSTRUCTION FRAMEWORK: PM 3366.80 -PM 3377.00	22 747 047,00
XIX-CONSTRUCTION OF CONCRETE CANAL AND CONSTRUCTION OF SCUPPER FRAME: PM 3625,00 -PM 3647,00	21 665 833,00
XX-CONSTRUCTION OF MANOEUVRE GATEWAY: PM 1325.00; PM 2291.00 and PM 2527.60	10 416 065,00
XXI-CONSTRUCTION TWENTY-THREE (23) PLOT HOLDS	10 341 536,00
XXII -RADIER ANDRANOLAVA	200 360 062,00
XXIII -CONSTRUCTION OF A GUTTER UNDER THE RUNWAY (RUNWAY INSIDE THE PERIMETER)	11 345 281,00
XXIV - RE-CONSTRUCTION AND RE-PROFILING OF EARTHEN CANAL	52 825 545,00
XXV-EARTHEN CANAL AND ENVIRONMENTAL TREATMENT	50 668 175,00
TOTAL AMOUNT	**981 787 204,00**

[3] As of 15th May 2023, UN official exchange rate is 1 USD = 4,396.42 MGA

RECAPITULATION	SELECTED ALTERNATIVE
0 PREPARATORY WORK	62 847 000,00
I-REMOVAL OF NOZZLE, DEMOLITION OF EXISTING HEADWORKS AND CHANNEL CONSTRUCTION CONCRETE COVER 100x100	33 973 532,00
II-PLACEMENT OF RIPRAP AT PM 25.00 AND CONSTRUCTION OF OVERPASS AND REHABILITATION OF THE DUMPING STRUCTURE : PM 119,00	47 776 631,00
III -STRUCTION OF TWO (02) OVERPASSES: PM 269.00 and PM 807.00	37 550 736,00
IV-CONSTRUCTION OF CONCRETE COVERED CHANNEL AT PM 375,00 LENGTH 50,00 ml AND INSTALLATION RIPRAP PM 350 - PM 362	52 570 892,00
V-RECONSTRUCTION WALL: PM 515.00 and PM 847.00	5 843 399,00
VI-CONSTRUCTION OF THREE (03) ZEBUS PASSAGES: MP 619.00; MP 1378.00 and MP 2835.00	26 722 023,00
VII-CONSTRUCTION OF CONCRETE COVERED CHANNEL AT MP 751,00 LENGTH 30,00 ml	28 607 189,00
VIII - INSTALLATION OF BUSE Φ50 AND CONSTRUCTION OF ARM CONCRETE FRAME: 12.40 ml LENGTH	10 493 364,00
IX-CONSTRUCTION OF WALL AND FALL WITH DISSIPATION BASIN : MP 901.00 to MP 972.70	27 111 924,00
X-DEMOLITION OF EXISTING WATERFALL, RECONSTRUCTION OF WATERFALL AND DISSIPATION BASIN : PM 1037 ,00- PM 1046.50	11 334 000,00
XI-DEPOSIT THREE NOZZLE Φ50 AND CONSTRUCTION TARPAULIN IN REINFORCED CONCRETE PM 1098,75 - PM 1126,90 : 28,15 ml	26 875 783,00
XII-DEMOLITION OF EXISTING STRUCTURE, REMOVAL OF NOZZLE Φ50 AND CONSTRUCTION OF REINFORCED CONCRETE COVER : 30,00 ml	32 935 200,00
XIII - REHABILITATION OF THE SHUTDOWN AND REHABILITATION OF THE CIRCULAR DALOT : PM 2000,00 to PM 2016,30	28 470 989,00
XIV-DEMOLITION OF THE EXISTING STRUCTURE AND CONSTRUCTION OF A PARTITION AT THE PM 2124,00	9 381 912,00
XV-REHABILITATION OF GUTTER AT PM 2925,00	5 252 403,00
XVI-DEMOLITION OF EXISTING STRUCTURES AND REHABILITATION OF THE COURIER AND TARPAULIN METAL N°01 : PM 3040,20 -PM 3090,70	79 933 074,00

RECAPITULATION	VARIOUS RETENTION
XVII - REHABILITATION OF METAL COVER N°02 : PM 3145,40 -PM 3173,20	73 737 609,00
XVIII - WATERING TROUGH AND GUTTER CONSTRUCTION FRAMEWORK: PM 3366.80 -PM 3377.00	22 747 047,00
XIX-CONSTRUCTION OF CONCRETE CANAL AND CONSTRUCTION OF SCUPPER FRAME: PM 3625,00 -PM 3647,00	21 665 833,00
XX-CONSTRUCTION OF MANOEUVRE GATEWAY: PM 1325.00; PM 2291.00 and PM 2527.60	10 416 065,00
XXI-CONSTRUCTION TWENTY-THREE (23) PLOT HOLDS	10 341 536,00
XXII -RADIER ANDRANOLAVA	200 360 062,00
XXIII -CONSTRUCTION OF A GUTTER UNDER THE RUNWAY (RUNWAY INSIDE THE PERIMETER)	11 345 281,00
XXIV - RE-CONSTRUCTION AND RE-PROFILING OF EARTHEN CANAL	52 825 545,00
TOTAL AMOUNT	**931 119 029,00**

Cost in USD: 219,790.28

	BENEFICIARIES' CONTRIBUTION				
XXV-EARTHEN CANAL AND ENVIRONMENTAL TREATMENT					
N°	DESIGNATION	U	QTE	PU	AMOUNT
113-a	Digging channel in earth 60x60	ml	170,00	21 900,00	3 723 000,00
402	Supply and planting of vetiver grass (Watershed)	m2	2 345,63	2 500,00	5 864 075,00
403	Supply and planting of Bararata (Watershed)	m2	153,75	2 000,00	307 500,00
404	Reforestation	ha	8,00	5 096 700,00	40 773 600,00
	TOTAL CONTRIBUTION OF BENEFICIARIES				**50 668 175,00**

The hydro-agricultural development (A) and the IWRM and new measures for runoff collection to support irrigation and managed aquifer recharge to support storage of groundwater for drought protection (B) are proposed as a combined and integrated approach to reduce climate risks.

A Steps for feasibility studies for a hydro-agricultural development in DEFIS+ sites:

The feasibility study will be based on the following basic studies:

For perimeter irrigation and drainage systems, the Design Office will carry out the reconnaissance of the perimeter and will establish a detailed inventory of the existing situation. This will deduce the measures to be taken so that the facilities are efficient and robust enough to withstand climatic hazards by referring to the NIHYCRI standards. However, the proposed developments must not lead to a substantial modification of the environmental conditions of the area.

Diagnosis of the current situation

The Design Office will study the documents available on the sub-project and on the project area. The consultants must establish the history of the development in terms of production, technical, socio-organizational events, etc.

Among the parameters to be examined, it is worth mentioning among others:

- The diagnosis of the current state of the perimeter and the watersheds directly impacting this perimeter;
- The environmental situation of the perimeter, any related problems
- The land study which must detect any land problems that may arise during and after the works;
- The possible options for the irrigation canals

A plot plan, even a summary one, must be established at the end of this diagnosis.

It should be noted that the analysis of the problems identified will be deepened during a series of meetings with the beneficiaries. The purpose of these meetings, which will lead to the creation of the management body, is to inform the farmers about the development (work defined in common, participation of the beneficiaries, future maintenance borne by the WUA). The Design Office will be invited to make amendments and additions when carrying out these diagnostic studies (to be specified).

Socio-economic study

The purpose of all the data collected during this study phase is, on the one hand, to define the current situation which will serve as a reference for profitability calculations, and on the other hand, to define the economic data necessary to assess the benefits induced by rehabilitation (post-project). The Design Office will have to collect as much information as possible on the activities and socio-economic practices of the areas to be developed as well as the major constraints experienced due to the current state of the developments.

It will thus carry out a socio-economic study detailing the monograph of the municipalities and large villages benefiting from the development (population, density, inventory of infrastructure social and economic with analysis of their accessibility by the population, basic data on the main economic activities, especially agricultural production, traffic study, development potential, etc.) and to highlight the following points:

- The baseline situation on the socio-economic characteristics of the irrigators, including the characteristics of the population and of the households cultivating the areas studied (structure, activities, income and sources, land situation, gender, etc.),

- The basic situation on the current production systems in practice on the perimeters studied with, the total areas developed/cultivated per household, the yields and incomes per hectare and per household (typical operating accounts),
- The organization of production, the possible supply of inputs, the marketing of production;
- The future organization of Water Users and the operating methods of user associations (deduction of contributions, nature and quality of interviews carried out, activities, etc.)

Socio-organizational study

This will analyse the ability of users to take charge of the management and maintenance of the perimeter and tracks and to propose solutions to ensure the sustainability of the rehabilitated infrastructure from a socio-organizational point of view.

- The study will take into account the following elements:
- Basic socio-organizational data of the sub-project (zero state);
- Detailed information on beneficiaries;
- Detailed information on the degree of urgency in relation to the food security situation;

Justification of the sub-project in relation to the objective of the DEFIS+ project;

- Analysis of the social viability of the sub-project (verification of the possible existence of strong constraints at the social level for the proper functioning of user associations and search for solutions);
- Verification, addition and possible formalization in the field of data in requests from WUAs. This service aims to:
    - Locate the irrigated perimeter with geographical coordinates (in decimal degree);
    - Collect existing documents from water users (list of members, estimated area per member, etc.);
    - Evaluate the organizational capacity of WUAs or Water Users and the operating methods of user associations (deduction of contributions, nature and quality of interviews carried out, activities, etc.)
    - Assess the capacity and willingness of user associations regarding contributions for future maintenance of the structures to be put in place;
    - Propose solutions and the necessary support, establishment of a training curriculum for user associations, particularly in socio-organizational matters and financial recovery (contribution) to ensure the management, maintenance and protection of networks for the sustainability of infrastructure.

Technical study

The Design Office will have to go through the entire site with the beneficiary population and consider the related desiderata. The technical study will establish a plot plan with identification of the direct beneficiaries (owners, sharecroppers, tenants, etc.). The technical study aims to:

- Inform the implementation of an efficient irrigation network to ensure better management taking into account the NIHYCRI standards of all works (calibration of channels, lining of channels, construction of works, perimeter protection, etc.);
- Mobilise of all water resources to irrigate the perimeter;
- Improve the drainage and protection against floods, obtained by recalibrating drains, cutting meanders or embankments, after having estimated the environmental effects of the developments;
- Install additional equipment: interior tracks, washhouses, drinking troughs, and water supply to the villages.
- Identify the components of the physical, biological and human environment that may be affected.

- Establish technical variants that can solve problems or prevent them
- Estimate the cost of the work to be carried out

Regarding the drainage and flood protection network, the drains will have the function not only of evacuating excess water from the perimeter plots, but also of evacuating rainwater from the watershed. Therefore, the study of floods will be based on hydrological data obtained during the baseline study. The choice of solutions, recalibration of drains, embankments, will be based on the results of the studies. The sub-project flows will be calculated based on the allowable flooding of the rice.

At the end of the assessment, an APS report will be drawn up specifying:

- The problems observed at the scope level and the specific study method envisaged to study them
- The limits of the perimeter, object of the rehabilitation and extension project
- Minutes and minutes of meetings
- Possible rehabilitation scenarios

The written pieces will present:

- The socio-economic studies will include the agro-socio-economic diagnosis and the proposal of organizational plans for the associations of beneficiaries, as well as the definition of the maintenance methods and all the minutes and minutes of the meetings;
- Technical studies, Diagnosis of the initial situation, basic studies and proposals for the main works to be put in place;
- Studies of the routes of the canals and/or drains with the list of landowners concerned by the new routes with an information meeting of the local population and the owners of the land concerned on the surface to be acquired and the impact of this acquisition on the socio-economic life of the households affected.
- The various necessary plans such as the plot plan, the ground plan, the longitudinal profiles and through the canals and drains, the plans of the flood fields and the geometry of the beds at the location of the reservoirs, the plans of the reservoirs and works.

Economic and financial study

The APS of the perimeter will contain technical variants with their respective costs for the realization of the sub-project. Each proposed variant will consider the improvement of the water control of the perimeter while respecting the social and environmental requirements in accordance with the requirements of the MECIE and the IFAD, and especially the respect of the timetable for their implementation without disturbing the agricultural activities of the beneficiaries.

Also, a financial and economic evaluation of each variant will be carried out by the design office. Thus, the technical solution(s) it will propose constitute the best compromise between cost and economic benefit and include at least the following elements: IRR/ ERR, NPV, ratios on the basis of situations with or without improvement will make it possible to justify its economic profitability. financial.

For all scenarios, the Design Office will identify the various problems that the User Association will have to solve for the management and maintenance of the rehabilitated network.

Thus, the APS file would include at least the following data:

Part A: General Data

- Description of the target population, the direct and indirect beneficiaries affected by the projects;
- Description of the perimeter and the current situation with diagnosis of the structures, canals, dykes and their annexes by inventorying the degradations and the sensitive points requiring repair and protection.

- Results of diagnostic studies at BV, land, socio-organizational, agricultural level… (part 6.2.1.1)
- Inventories of lodgings, borrow pits and other construction materials;
- Overall plan showing the location of the proposed project on topographic maps, scale 1:50,000.

Part B: Specific Data

- Verification of the condition of structures and canals with diagnosis and causes of degradation, and details of the work to be carried out accordingly;
- Brief description of the variants proposed with the related brief technical studies;
- Results of the recognition of the floors of the platform, the lodgings and other construction materials;
- Summary proposal of the routes of the canals and/or drains with the list of the owners of the land concerned by the new routes provided with the letters of donation of the land or others;
- Results of the socio-economic study
- Results of the cost/benefit analysis as well as the presentation of the advantages and disadvantages from a technical and environmental point of view for the different variants proposed, in order to allow the best solution to be selected on a technical and financial basis.

Part C: Appendices

- Perimeter ground plan;
- Detailed plan and survey at the reservoir site;
- Development plan at the location of the reservoir with presentation of the flood fields and the geometry of the beds;
- Overall plan showing the location of the proposed project, scale 1:50,000
- The longitudinal and cross profiles for canals, drains, rivers and dykes (The survey of the canals will be at least one long profile every 100 meters and one cross profile every 50 meters. Insufficient or poorly constructed structures wedged (siphon, tarpaulins) will be projected according to the new flows and water lines).
- Standard plans of the planned works
- Map of the initial location of borrow pits and quarries
- Minutes of all meetings conducted with the client and with the beneficiaries
- Formal request for rehabilitation emanating from the beneficiaries with the list of beneficiaries

For intra-perimeter tracks

The main objective is to restore the tracks inside the perimeter if there are any or to create them if they do not yet exist in order to allow vehicle access (motor cultivator, mini-tractor, cart). Also, the design office will take into account the avenues to be taken during the future maintenance of the canals, drains and protective dykes and for the mechanization of work in the rice fields. Thus, He will evaluate the problems of use of the tracks and will describe the project by:

The socio-economic study which will highlight the activities and practices of users in the axes to be developed as well as the major constraints experienced due to the current state of the tracks;

The technical study, which will highlight:

- the structure, geometry, components of the physical, biological and human environment that may be affected, the type of sanitation, the nature of the structures, their condition, and in particular the hot or critical points, of the axes of the tracks considered in a rapid recognition with the beneficiary population;
- the choice and prioritization of the axes of roads to be rehabilitated, in consultation with the beneficiaries, and the advantages to be drawn therefrom;

- the presentation of the proposed project: location of the infrastructures and the consistency of the project;
- the design variants of works, the different plans (Layout and transverse profiles for the existing tracks, to be opened or sections to be modified, standard roadway plans, drawn parts, etc.) and the summary quantitative and estimated estimates, a programming indicative of the work.

The financial study which will evaluate the cost of each technical option proposed and the evaluation of the maintenance costs. Thus, he made recommendations to ensure the economic and financial viability of the project.

B Steps for feasibility studies for a Integrated Water Resources Management and Managed Aquifer Recharge:

The feasibility study will be based on the implementation of three phases: Inception phase, design and planning phase and implementation phase.

During the inception phase all the available data on water resources and demands will be collected and aggregated to provide a summary report on the hydrological conditions and the hydrological infrastructure in terms of monitoring as well as the institutional and socio-economic aspects of water management in Madagascar. This phase will last three months and will be concluded with a workshop in which the stakeholders will be informed about the current status of water management in the study region. The main objective is to establish, the amount of water available, the needs and demands, the summary of plans and decisions taken to affect the water sector and an overview of actors and stakeholders in the water sectors.

IWRM structures identified, activated or created

The second phase will establish the foundations of integrated water resources management. The first action is to define the existing watershed structure for IWRM in the study area. The project will use the available structures for IWRM and expand them in three aspects:

- Major Management Basins in the study area: This is the key structure for Integrated Water Resources Management (IWRM) in the study area and associated with the project. According to a pre-assessment, the study area is subdivided into three major drainage basins (each of basins sizes of > 1000 km²), the existing structures and actors will be identified, if structures are missing, they will be created.
- Each of the major drainage basins will be further subdivided into sub-basins and the drainage network will be identified and named with its tributaries at meso-scale level (< 1000 km²) for a regionalization of data (meso-level).
- The planed infrastructure of the project in terms of irrigation, road-water-collection and recharge will be integrated into this basin management structure (micro-level).

The basin structure is key for the implementation of IWRM, therefore the delineation will be vetted and discussed with the institutions in Madagascar, all actions of the projects and infrastructure, irrigation and managed aquifer recharge measures will hence be integrated into the IWRM network (if available and functional). If the structures are not sufficient or active, they will be activated or created in terms of basin committees and stakeholder meetings.

Diagnosis of the current situation of IWRM

An IWRM team with an experienced expert and mobilized experts on specific IWRM and hydrology and recharge topics will evaluate the water resources conditions in the key IWRM basins and assess, the available rainfall, actual evapotranspiration, runoff and groundwater recharge and storage precisely.

Among the parameters to be examined:

- Precipitation with annual mean, quantiles, time series and trend analysis, drought occurrence, seasonal distribution, duration curves, recurrence intervals for all three key basins and down to the meso- and micro level with a resolution of 1 to 10 km² to assess the present state and future states all projects will be exposed to
- Evapotranspiration with annual mean, quantiles, time series and trend analysis, including the analysis of key parameters such as wind speeds, temperatures, and relative humidity according to the best practice with Penman-Monteith, Grass reference.
- Runoff with annual mean, quantiles, time series and trend analysis, hydrological drought occurrence, seasonal distribution, duration curves, recurrence intervals for all three key basins and

down to the meso- and micro level with a resolution of 1 to 10 km² to assess the present state and future states all projects will be exposed to
- Groundwater levels with time series and trend analysis, seasonal variation, duration curves

The analysis will be based on three data-driven approaches:

- Analysis of the existing station networks for precipitation, meteorology and hydrology, as well as groundwater: All available data will be identified, collected and analyzed
- Use of modern satellite-based and globally aggregated data sources such as precipitation MSWEP (Princeton), GDLAS 2.2 for hydrological water balance components evapotranspiration, runoff and groundwater storage at daily resolution for the study area, as well as satellite-based GRACE data for groundwater storage fluctuations
- Additional monitoring activities in the project area to validate these data sources with fully automatic stations for precipitation, meteorology and water levels in rivers and groundwater wells

This step will establish the availability of water in terms of surface and groundwater and be the basis for IWRM assessment of all infrastructure projects' feasibility as well as impact studies.

Socio-economic study for embedding all measures into IWRM

For the three IWRM basins a socio-economic study in terms of water needs, developments and stakeholders will be used from the previous feasibility studies. The Design Office will evaluated the collected information in terms of water pressures to be expected for different time horizons. It will thus evaluate the socio-economic study detailing the municipalities and large villages benefiting from the development (population, density, inventory of infrastructure social and economic with analysis of their accessibility by the population, basic data on the main economic activities, especially agricultural production, traffic study, development potential, etc.) specifically for IWRM including:

- The baseline situation on the socio-economic characteristics of the water management activities such as runoff collection and recharge, including the characteristics of the population and of the households in the areas studied (structure, activities, income and sources, land situation, gender, etc.),
- The basic situation on the current production systems that could benefit from runoff collection and managed recharge, the total areas developed/cultivated per household, the yields and incomes per hectare and per household (typical operating accounts),
- The future organization of Water Users and the operating methods of user associations (deduction of contributions, nature and quality of interviews carried out, activities, etc.)

Socio-organizational study for IWRM

This will analyse the ability of users to take charge of the management and maintenance of the runoff collection and managed aquifer recharge from a socio-organizational point of view.

- Basic socio-organizational data of the sub-project (zero state);
- Detailed information on beneficiaries;
- Detailed information on the degree of urgency in relation to the runoff collection and groundwater storage;

Justification of the sub-project in relation to the objective of the DEFIS+ project;

- Analysis of the social viability of the sub-project (verification of the possible existence of strong constraints at the social level for the proper functioning of user associations and search for solutions);
- Verification, addition and possible formalization in the field of data in requests. This service aims to:

  - Locate the runoff collection sites along roads and recharge sites with geographical coordinates (in decimal degree);
  - Collect existing documents from adjacent water users (list of members, estimated area per member, etc.);
  - Assess the capacity and willingness of user associations regarding contributions for future maintenance of the structures to be put in place;
  - Propose solutions and the necessary support, establishment of a training curriculum for user associations, particularly in socio-organizational matters and financial recovery (contribution) to ensure the management, maintenance and protection of networks for the sustainability of infrastructure.
- Creating a IWRM structure within the basins connected the projects from the micro-scale of measures to the integrated basin scale and providing all projects with updated hydrological data.

Technical study

The Design Office and associated expert team will establish a detailed design plan with identification of the direct beneficiaries. The technical study aims to:

- Inform the implementation of an efficient runoff collection and managed aquifer recharge scheme network;
- Mobilise additional water resources;
- Improve the drainage and protection against floods by creating additional retention storage;
- Improve the protection of water supply and irrigation schemes against drought by additional groundwater storage;
- Identify the components of the physical, biological and human environment that may be affected.
- Establish technical variants that can solve problems or prevent them
- Estimate the cost of the work to be carried out

The runoff collection and managed aquifer recharge schemes will constitute an important climate adaptation and mitigation infrastructure and activity that aims at compensating for the impacts of climate induced extension of dry periods and seasonal reduction of rainfall. It will secure investment into irrigation schemes and infrastructure.

Economic and financial study

The economic and financial aspects of each scheme for runoff collection and managed aquifer recharge will be assessed in terms of cost per m³ of water for drinking water use or irrigation demand. The financial and economic evaluation of each variant will be carried out by the design office. The technical solution(s) it will propose constitute the optimal design taking into account the costs and benefit analysis. For all scenarios, the Design Office will identify the various problems that the User Association will have to solve for the management and maintenance of the infrastructure.

IWRM Observatory for the study area

For the study area an IWRM observatory will be created providing hydrological data on annual, seasonal and event-base to all stakeholders for the operation of runoff collection and groundwater recharge structures. The objective is to inform about climate and meteorological events such as floods and droughts and also assess the functioning of the innovative runoff collection and recharge measures. The observatory also assures the sustainability of the water resources in the project area and prevents depletion of resources, helping to balance irrigation and food production with drinking water supply and availability of water resources in changing climate conditions.