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to

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Project Title
Underutilized Cactus Pear (Opuntia ficus-indica) for Sustainable Livelihood under Changing Environment and for Mitigation of Land Degradation in the Arid Regions

Thematic Area
Forestry and Agro-Forestry

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Yemen; Hajjah, Taizz and Sana’a areas

Regional Counter-part
Ministry of Industry, Environmental Protection Authority (EPA), Investment Agency, Ministry of Agriculture and Rural Development

Executing Agency
GAFÉIAS

GENERAL INFORMATION ON GAFÉIAS
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Underutilized Cactus Pear (*Opuntia ficus-indica*) for Sustainable Livelihood under Changing Environment and for Mitigation of Land Degradation in the Arid Regions
1. Background

1.1 Ethiopia

Cactus pear (*Opuntia ficus-indica* L.) is one of the economically valuable but neglected and underutilized crops which can tolerate harsh environment. The unique characteristic of the plant to adapt extreme environments makes the plant high potential in mitigation of land degradation while satisfying the government targets towards poverty alleviation. Consequently, the project considered the degraded areas of Eastern part of Tigray to rehabilitate and enhance the productivity and utilization, value addition and value chain development of cactus pear product to improve the livelihood of the rural poor community.

The project will focus on youth and women associations who have already experience on cactus pear collection, processing and marketing. The project will work together with Bureau of Agriculture and Rural Development (BoARD) cooperative section to organize and built the capacity of the existing youth and women cooperatives specialized on production, collection, processing and marketing. The cooperatives will be trained on; (1) plantation management, (2) harvesting and postharvest handling, (3) hygienic processing and packing techniques, and (4) marketing (on value chain development, promotion and communication).

Cactus product processing unit will be established in the centre of the collection areas.

The opportunity for accessing global carbon financing will be considered in the project. The project, in addition to its local importance, it will take part in satisfying the majorities of MDGs, such as Goal 1: (Eradicate Extreme Poverty & Hunger), Goal 3: (Promote Gender Equality And Empower Women), and Goal 7: (Ensure Environmental Sustainability).
1.2 Yemen

Yemen is one of the Arabian Peninsula Regions with considerable water-stressed areas that exhibiting extreme aridity and having limited renewable water resources. In most part of the countries except very few areas, the annual precipitation is far below the potential crop requirements for water, as a result all crop production areas require irrigation, which is very expensive for agricultural development. Moreover, marginal lands need potential crop which can tolerate such harsh environment and support the livelihood of the poor community.

Yemen is located in the south west Arabian peninsula and is one of the oldest agricultural civilizations as evidenced by archaeological excavations, remnants of irrigation structures and terraces (Varisco, 1987). Yemen is situated in the northern stretches of tropical climate zone. The temperature varies greatly to extreme differences in the elevation. The annual temperatures range from less than 15°C in the highlands region to 40°C in the coastal plains and to 45°C in the eastern plateau (Desert and semi desert areas). The rainfall is highly erratic in time, quantity and location. It occurs in two periods, the first from early March through May, the second from July until September, but there are exceptions in certain regions and years. Rainfall varies from less than 50 mm in the coastal region and desert plateau, to more than, 1200 mm in the western mountainous highlands (Al-Khurasan, 2005). The total land area of Yemen has been estimated at 55.5 million hectares with only 3.5 million ha considered as arable land. Water scarcity imposes a yearly limit on the cultivated area of 1.4 million ha of which 42-45% is under irrigation (vegetables and fruits). The remaining rain-fed areas consist mainly of cereals and legumes. The contribution of agriculture to the gross national product (GNP) is about 17%

Cactus Production in Yemen

The widely cultivated species of Opuntia in Yemen are; Opuntia ficus-indica L., Opuntia ficus-indica inermis and O. dillenii (Ker-Gawler). Opuntia ficus-indica was planted in the 16th century in the Mediterranean area for their sweet fruits and has become a cheer character plant (Ellenberg, 1982 ). It was brought to Yemen by
the Turkish people during their occupation of Yemen in the late 16th century. For this reason cactus (Opuntia ficus-indica) is known in Yemen as the Turkish fig.

**Economic importance of Cactus plantation in Yemen**

The economics of cactus pear cultivation have been quite favorable. For example, the farmers have been obtaining about 19 tons per hectare of fruit from which they obtained a profit of more than US$ 3000/ha. In 2007, the area of cactus cultivation increased by 32% in the northern highlands. The number of farmers growing Cactus is increasing. In the year 2007 (production from April –October, a farmer cooperative union started to export fresh fruit to the neighboring countries. The first export was approximately 180 tons with value of more than US$ 1 million. The farmer’s cooperative union in the highlands increased their income in 2007 to 700,000 US$.

**Cactus Research in Yemen**

In 2003, The Yemen Agricultural Research and Extension Authority (AREA) in cooperation with Peter Felker initiated a field trial and research program to compare Yemeni local varieties with improved selections from Argentina. Also two surveys were conducted in June 2006 and May 2007 in the western, southern and central highlands to study the morphological, production, quality and socioeconomic characteristics of cactus (see Map 1 at the end of the chapter). The colours, soluble solids are similar to the well-known Italian Varieties Gialla, Rossa and Bianca described by Barbera et al. (1). The reason might be due to their historic background that both the Italian and Yemen varieties had similar origins from the early introductions to Spain by Christopher Columbus. In addition the fruit weights were very similar to the Italian fruit weights. Gugliuzza et al. (2) obtained from 15 fruits to 6 fruits without thinning and irrigation. However, through irrigation and management it is possible to significantly increase their size


and production. The percentage of pulp to whole fruit was 45.6 and was lower than the Italian varieties.

**Project Description and Proposed Activities**

The project will empower the poor rural community in achieving food security and importantly will rehabilitate the degraded marginal lands of the project area. The majority of the country’s land is categorized as drought prone area. The project will cover about 500,000 ha of the degraded and drought affected areas of the central highlands of Yemen. The plantation program will consider screening of potential cactus cultivars and based on the required parameters will be taken for plantation. In addition to the production of cactus the project highly promote carbon financing in the country. The project will cover about 500,000ha of degraded and marginal lands. It is estimated to sequestrate 30 tCO2/ ha/ year after the establishment of the plantation on degraded marginal lands. The implementation of the project will be based on Community Based Organized approach. To have a historic baseline data a high resolution remote sensing technology will be used.

The principal activities of the project encompass high production, genetic improvement, postharvest technology, marketing, reclamation of degraded areas, increasing carbon storage potential. Among the plantation management activities fertilization, pruning, fruit thinning and irrigation will be considered. Fruit thinning and irrigation during fruit filling are important to increase fruit size for export. Due to the high temperatures in the Arabian Peninsula, fruits are quite perishable. Thus the project will give a due attention to provide technical assistance to adequately de-spine, cool, package and ship the fruit to obtain acceptable quality on arrival. Marketing promotion for Arab Gulf countries with which Yemen has excellent relations and which are close will be the project’s first priority. As Yemen has one of the few high elevation sites in the Arab Countries with cool temperatures, where Opuntia flowering and maturation would be delayed, special consideration will be given to cultivation and marketing fruits from high elevations to produce off season fruit for export to all the Mediterranean and Europe. Integration of Agroforestry technology which considers animal husbandry and Cactus plantation will be one of the major activities of the project to combat the scarcity of animal
feed in many parts of Yemen for optimal production of meat and dairy products from livestock. To achieve the targeted objectives of the project, improved verities of Cactus will be evaluated based on multi-location adaptation experiment over all potential ecological zones of the country. Furthermore, application of advanced technology in quality identification will be implemented using metabolomics technologies and molecular markers will be developed for characterization of productive and resistance varieties. Countries which are possible sources of Opuntia varieties are Mediterranean countries, Latin America, Central America, and North America.

**Proposed project locations in Yemen:**
The prior project locations will be situated in Western (region around Hajjah), Southern (region around At Turbah, Al Hugariah district, south of Taizz) and Central Highlands (region around Sana’a)

**Map 1: Location of study areas in Yemen (Saif A. and Muharram I., 2009)**
**Counterpart organizations (for technical cooperation)**

AREA, the Agricultural Research and Extension Authority (Yemen), Ministry of Agriculture (Yemen), EPA, Environmental Protection Authority (Ethiopia) and Ministry of Industry (Ethiopia), are the major counterpart government institutions for Yemen and Ethiopia, respectively. Both AREA and EPA will provide research stations, land for community based plantation, technical support, locally available facilities and providing other enabling environment which could support the achievement of the targeted objective.

2. **Problem Analysis (Ethiopian Dryland)**

Northern Ethiopia is one of the regions in the country with considerable water-stressed areas that exhibit extreme aridity and have limited renewable water resources. The majority of the communities are highly dependent on crop and livestock production. However, the agricultural productivity is low and, hence, negatively affects the income of the rural communities. In most parts of the region, the annual precipitation is far below the potential crop requirements for water and, as a result, all crop production areas require irrigation, which is very expensive for agricultural development.

Moreover, many of these areas are heavily degraded, and the potential risk of desertification of these ecosystems poses the greatest challenge on the local communities. The recurrent drought coupled with human associated factors, are aggressively increasing the impact. The communities living in such areas are facing extreme poverty, generally lacking access to health care services, schools and credit services, and other necessary infrastructures, such as roads, are either absent or often in poor conditions.

Consequently, to sustain the welfare of local communities in the arid and semiarid areas of Northern Ethiopia, it is critically important to focus on sustainable commercial agricultural systems linked to processing industries. In a harsh environment, such as in northern Ethiopia, it is important to base commercial
agricultural systems on plant species that can adapt to the changing environment, i.e. extreme temperature, insufficient water availability and poor soil conditions.

In general, the major problems facing the local communities in northern Ethiopia that need to be addressed through the proposed project include:

1. increasing land degradation and the associated risks of desertification (which lead to lower productivity and food insecurity);

2. recurrent drought and limited availability of tolerant species in a changing environment;

3. lack of modern post-harvest handling technology and preservation of agricultural products which lead to high production loss and associated environmental implications - though the FAO project (GCP/ETH/073/ITA) addressed the agronomic and harvesting techniques of cactus, the modern post-harvest handling technology and preservation (i.e. the technique to reduce product loss until it reaches the processing centre) were not well established.

4. lack of knowledge and skills of local communities in processing and creation of added value addition of agricultural products;

5. lack of potential and sustainable marketing and poor value chain development;

6. lack of awareness, knowledge and skills to promote commercialization of marginal lands and limited technical and institutional support from the relevant authorities;

7. limited infrastructure development; and

8. lack of capacity in developing, implementing and monitoring CDM projects

9. lack of access to traders and fruit packers respectively processing companies

10. lack of marketing and sales management

Cognizant of the above mentioned problems, the proposed project will promote further expansion as well as proper management, sustainable utilization and conservation of old and newly established private and community-based stands of cactus pear, *Opuntia ficus-indica* (L.) Mill. (hereafter referred to as OFI) and
production, processing and marketing of its various products. OFI is a unique multipurpose plant species that belongs to the family *Cactaceae* and widely planted or naturalized in the different parts of Tigray and other parts of Ethiopia. There are a number of inherent characteristics that make OFI unique and, therefore, excellently and specially suited to address the problems enumerated above.

OFI has the potential to play a significant role as a supplement to other crops, and its fruits (also known as tunas, tuna singular) can be used for food and feed by humans and livestock, respectively. Fruit production was reported to average from 5-8 and 20-30 tonnes ha-1 year-1 with minimal management in Mexico and under intensive plantation management in Sicily (Italy), respectively (3).

The young stems segments/cladodes/pads (also known as nopales, nopal singular) are usually picked before the spines harden and eaten. The cladodes/pads are also important sources of animal feed, especially during drought conditions, though they are low in dry matter and crude protein. In addition to their feed values, the high moisture content of the pads virtually eliminates watering the animals and the human effort in achieving that laborious task. These useful characteristics of OFI play tremendous roles in ensuring food security in drought prone areas, such as northern Ethiopia. OFI is also useful for producing honey (flowers), juices, jams, jellies and candies (fruits), edible flowers, oil (seeds) and gum (stem), alcoholic drinks (fruits), candles (gum), cosmetic products, medicine, additives in earthen plaster (stem/cladode juice) and red dye used in the food, cosmetic and textile industries (associated insect). The species has also been reported to have significant cultural importance in several countries.

OFI also plays crucial roles in the provision of various environmental/ecosystem services, such as sequestering carbon, thereby, contributing to the regulation and mitigation of global warming/climate change, source of feed and breeding ground for different organisms, thereby, conserving and enhancing biodiversity, conserving soil and water resources, regulating watershed, restoration of degraded land and water resources, etc.

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The unique ability of cactus pear to produce large biomass/sequester CO₂ by growing on rocky and very marginal areas could lead to an additional benefit of accessing Clean Development Mechanism (CDM)-based voluntary carbon markets/financing by the local communities. For example, it is proven that cactus pear can have a biomass gain of 20 tonnes of dry weight ha⁻¹ year⁻¹. Evidently one tone of biomass is equivalent to 1.5 tonnes of CO₂ equivalent (4). This implies that on a 0.5 ha farm land, with predicted productivity as above, the cactus pear can sequestrate 15 tonnes of CO₂ equivalent generating an income worth of US$ 300 year⁻¹ (15 tonnes x US$20 ton⁻¹ = US$ 300 year⁻¹) for the farmer in Tigray. Over longer periods of time, this will ultimately contribute to the alleviation of poverty in the region.

3. **Envisaged activities to achieve the targeted objectives**

3.1 *Increase the quantity and quality of production of tunas, nopales and seed oil for human food and industrial inputs*

The proposed project will engage local communities in improved management of already established stands and expanding plantations of cactus pear in degraded landscapes with the ultimate aim of increasing the quantity and quality of tunas, nopales and seed oil for human food. In addition, the project will aggressively introduce and scale-up the best practices of processing the tunas and nopales into diverse dishes, sweets and drinks, including ways of increasing their shelf time, not only for domestic consumption but also for local, national and international markets.

3.2 *Increase the quantity and quality of production of cladodes for animal feed*

Tigray region is characterized by considerable water-stress that exhibit extreme aridity and has limited renewable water resources. As a result, availability of

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sufficient water and feeds has become bottlenecks for economic development of the region through livestock production. As stated earlier, cactus pear has a unique quality of thriving in such arid and highly degraded areas and providing feed and water for livestock. Hence, development of cactus pear plantations will increase livestock productivity and improve the income of the poor communities in the region.

The proposed project will engage local communities in improved management of already established stands and expanding plantations of cactus pear in degraded landscapes with the ultimate aim of increasing the quantity and quality of cladodes for animal feeds. In addition, the project will address limitations of the cladodes, such as spines and low nutrient contents through expanding plantations of spineless varieties and mixing them with other nutritious feeds. Innovative ways will also be introduced to process post-harvest losses from tunas, nopales and cladodes into animal feeds.

3.3 Preventing or reducing pre- and post-harvest losses of and adding value to products of cactus pear

Two major challenges of cactus pear growing local communities in Tigray are post-harvest loss of, especially tunas (estimated at > 60% in some areas), and absence of value adding initiatives. Therefore, the proposed project will address these problems through different approaches:

1. prepare and deliver relevant and properly packaged series of awareness creation and targeted training programmes on all aspects and the crucial importance of cactus pear, its various products and the available and potential markets to all stakeholders at various levels, including policy makers;
2. introduction of row planting and appropriate spacing in plantations for better management of stands and harvesting products;
3. promotion of the use of protective clothing, i.e. overalls, eye protectors, hand gloves and shoes, vacuum nozzles during harvesting;
4. introduction of improved harvesting tools and temporary storage facilities in farmers’ house as well as collection and processing centres;

5. improvement of logistic infrastructure such as existing road networks and constructing new feeder roads to production areas for fast and convenient transportation of cactus pear products;

6. improvement of carriages used for transporting cactus pear products from sites of collection to despining (removal of spine from fruits), calibrating, packaging and processing units collection and processing centres;

7. establishment of a more efficient transportation systems from sites of collection to the collection and processing centres, e.g. hire trucking service resp. purchasing cars (pickups and/or trucks), which will be dedicated to transport both raw and processed cactus pear products;

8. establishment of well-equipped collection centres at strategic locations of the cactus pear producing areas owned and managed by local communities/ cooperatives;

9. establishment of well-equipped integrated semi-processing processing, packing and marketing centres owned and managed by local communities/ cooperatives and the final product processing for regional and international market will be owned by NutrAfrica, the farmers in Ethiopia from Adigrat, Mekelle, Enda Mehone, Kobo and Sekota, and in Yemen, Western (region around Hajjah), Southern (region around At Turbah, Al Hugariah district, south of Taizz) and Central Highlands (region around Sana’a) will be organized in cactus pear production cooperative.

10. identifying local, regional, national and international (niche) markets for the different cactus pear products locally, nationally, regionally and internationally, and establishing a feasible system of market intelligence to ensure sustained access to existing and potential markets of cactus pear products; and

11. promotion of cactus pear products industrially and linking them to the identified (niche) markets

12. make acquisition of equipment sustainable through financing based on harvest output, thus raising the farmers ´and cooperatives ´attention towards the value of their purchased machinery and its need for maintenance
3.4 Organizing different groups, i.e. farmers, women and youth, into cooperatives

At present, all operations from planting to harvesting, consumption and marketing of cactus pear products are carried out at a household/individual level. There have been encouraging initiatives to establish agricultural cooperatives of different groups, e.g. women and youth (e.g. in Adigrat and Agula), focusing on harvesting/processing and marketing of diversified products of cactus pear by various private as well as government and non-government organizations. However, even this very few initiatives have not been successful owing to different reasons, e.g. lack of capacity (financial and physical resources), awareness, knowledge and skills necessary to manage, harvest, process and market cactus pear products, different markets outlets for their products, support from concerned authorities, etc. Despite their disappointment and frustrations so far, they are still very keen and eager to continue as members of the cooperatives provided that they receive the necessary support from concerned bodies and their capacities are built.

Therefore, the proposed project will revitalize and strengthen the existing cooperatives and organize as many rural and urban cooperatives of farmers/city dwellers, women and youth as feasible to be engaged at the various levels of the value chain in the establishment and management of cactus pear plantations as well as harvesting, processing and marketing of cactus pear products.

Women are invited to raise their farming output through acquisition of specific knowledge and equipment on a microfinance basis. They are motivated to raise quantity and quality of their output in order to pay back their credit and sustain their living standard but also to save some money for hard times and their children’s future. Later some of them may want to expand their micro enterprise and fuel local economy.
3.5 Promotion of processing of various products from cactus pear

One of the interventions in the proposed project will be to procure and execute processing methods to establish a sustainable industrial production environment and a stable supply of marketable products of OFI. The industrial transformation of fruits and pads of OFI into various high-quality food commodities will increase their chances of being traded in both domestic and international markets. A conservative and outweighed reinvestment of crop sales will facilitate specialization and product diversification and increase economic results.

The levels of efficient product transformation will be evaluated and selected. Based on research findings, appropriate infrastructure and logistics will be implemented for different processing phases for fresh food, such as crop handling, de-spining, cleaning, calibrating, labeling, packaging, storing, loading and shipping. Processed food, which will be transformed into juice concentrate, dried fruit, powder, purée, etc., demands additional machinery. GAFÉIAS will take responsibility for the composition of necessary investment and lean production plus the implementation on granted land sites.

Intermediate frozen, dried, squashed and extracted products will be promoted for packaging and processing in Yemen and Ethiopia as well as exported as food commodities for further packaging or processing. Traded commodities are besides bulk and packaged fresh fruits, juice concentrate, purée, frozen and dried fruit, powder and extracts. Fruits and pads are important for both processing industries and cattle feed. Marketed products in industrialized countries are beverages, candy, juice, marinated food, wine, jams, jellies, syrups, ice creams and sorbets but can also be used as ingredients in yoghurt, muesli, cocktails, etc. The remainder is used as raw feedstock for small local food industries.

Post-harvest threats include lack of knowledge of the behavior of this fruit, lack of record of costs and high informality in the marketing of cactus pear in the domestic market. The pads of some varieties are covered with stiff thorns, while the fruit has detachable microscopic hairs, called glochids that can easily penetrate bare skin. This painful experience scares off untrained workers. As a result, cactus pear
processing is slow and expensive because skilled labour is required. Inexpert fruit handling can cause crop losses up to 10%, which reduces the shelf-life, vigour during transport, visual appearance of the fruit and the income of farmers. Hence, besides industrial inventory, the training of farmers and workers is crucial for a successful project. For instance, a similar project in Chile proved that 25% of all farmers trained showed interest and welcomed innovation. These farmers were eligible to specialize in processing services on a micro-enterprise basis. The less flexible farmers can follow their traditional activities that are not innovative but still part of the post-harvest processing and will act in the framework of a cooperative enterprise.

As indicated earlier, the proposed project will facilitate the establishment of well-equipped integrated processing, packing and marketing centres, which will be owned and managed by local communities/cooperatives at Adigrat, Mekelle and Enda Mehome; Yemen: Western (region around Hajjah), Southern (region around At Turbah, Al Hugariah district, south of Taizz) and Central Highlands (region around Sana’a). It is envisaged to process cactus pear into three products, namely green/liquid (fresh fruits, jams, juices, jellies, nopales, cladodes, honey, etc.) dried (fruits, candies, cladode flour-based bread, flowers, etc.) and oil (seeds) products, which necessitates dividing the integrated processing centres into three parts for processing the three products.

The selection of the industrial processing equipment will strongly depend on the available quality and variety of plants which qualified for systematic cultivation and on the export market demand as well as the establishment of the most apt trade links. Simultaneously our cooperation with Mekelle City Centre of Trade and Industry will enable a selection of existing small and intermediate enterprises who qualify for contracting industrial services such as logistic and processing activities in the value chain development.
3.6 Exploration, identification and promotion of markets and market channels

Efforts will be made to establish commercial distribution of products of cactus pear to Austria (e.g. AGRANA), Oman, Saudi Arabia, United Arab Emirates taking chance of the comparative advantage of the proximity of the geographic location of Ethiopia and its traditional trading links with the Arabian countries. In order to meet the increasing global demand, production of cactus pear is steadily growing in South America and North Africa, as well as in Israel, Italy, South Africa and the United States. Export marketable fruits are typically 20 to 70 mm in diameter. Lower graded quality will be sold in the national market and to the regional processing industry.

In comparison to the Tigray local retail price of around USD 0.20 per kg, an average FOB US port price of USD 2.5 per kg for Chilean or Mexican origin can be highlighted in order to show the theoretic economic potential of applied processing and marketing strategies. Naturally, differences of quality, such as variety, diameter, appearance, condition, value chain stages, sales structure levels, regional market characteristics, consumer lifestyle, purchasing power, etc., should be considered.

The proposed project will assist in the identification of national and international (niche) markets for the different cactus pear products locally, nationally, regionally and internationally, and establishing a feasible system of market intelligence to ensure sustained access to existing and potential markets of cactus pear products. In addition, it will be engaged in the promotion of cactus pear products aggressively and linking them to the identified (niche) markets.

For example, the crop will be reduced by handling losses (5%) and minor direct farm sales to end customers (2%) in some countries. The balance will typically sell via cooperatives and auctions as well as through the whole sale to the retail market (82%). The export of cactus pear is a relatively small percentage of domestic production (1%). The fruit exported is of high quality and its main destination is the
USA by air. However, export volumes have been in a small scale due to low development of production, post-harvest management and marketing.

To build efficient sales structure agents, distributors, fruit packers and industrial customers will be selected for each targeted export market. All marketing activities efficiency oriented and based on long term market demand will be selected. This will have impact on cultivation, crop and post-harvest management, such as crop handling and storage but also mechanization and training processes seeking maximization of output. This will lead to the establishment of improved agricultural output - both in quality and quantity – and sound export channels through a continuous offer of export grade fruits and processed products. The project will aim at creating a highly appreciated brand image of the cactus pear products from Ethiopia in the international consumer markets.

3.7 Identifying and promoting healthy food, pharmaceuticals, food supplements and other potential products from cactus pear

The proposed project will actively promote cooperation with the international food technology industry to take chance of the OFI as a valuable source of biochemical substances, which can be used in pharmaceutical and health food industry. OFI is rich in bioactive compounds and antioxidants as ingredients for the production of health-promoting food. Additionally, OFI provides highly nutritious food with low levels of saturated fat and very low levels of cholesterol. It contains sodium, calcium and potassium. The fruit is rich in antioxidants (beta-tocopherol) (anti cancer), amino acids, fibres and B vitamins. Other contents are ascorbic acid, flavonoids, betalains, taurine, total carotenoids and total phenolics.

Nopal stands for the processed cactus pad in Mexico and is rich in dietary fibre as well as in magnesium and vitamins A and C. The pectin found in Nopal helps to lower blood sugar levels for people that experience issues with high blood sugar and LDL-cholesterol. Betalains combat free radicals, which can attack cells within the human body and cause aging effects. Nopal products can be used as diabetic and cancer protective nutriceutical but also for babies and young women during motherhood as nutrition supplement.
The species can also be used as a feedstock for bio-ethanol and biomass production. The usability of functional construction material such as textile velts and insulating panels seems to be worthwhile proving.

3.8 Restoration of degraded land through cactus pear-based agroforestry

The proposed project will mitigate the problem of degradation of land and water resources discussed earlier through the expansion of commercial cactus pear plantations, and production, processing and marketing of the various cactus pear products. This will be achieved through the enhancement of the productivity of degraded areas through the application of cactus pear-based agroforestry technology. Through collaborations with potential partner institutions, the proposed project will conduct survey and delineate degraded and less productive lands in the targeted districts and develop management plan(s) to restore degraded lands and maximize their productivity. Rate of change of land degradation will be assessed and potential of cactus pear plantations in restoration of degraded land will be verified so that it can also be replicated to other regions.

Converting the degraded and abandoned areas into commercial-based cactus pear production will reduce human pressure on natural resources, deforestation and free grazing, which generally affects regeneration in natural and plantation forests. Ultimately, the project will contribute towards reduced soil erosion, improvement of soil fertility, restoration of water resources through reduced siltation and regulation of watershed as well as enhancement and conservation of biodiversity.

3.9 Promote the opportunity for accessing global carbon financing

As stated earlier, the other potential benefit that can be derived from the cactus pear plantations established to restore the degraded areas is the added opportunity for accessing the global voluntary carbon markets/financing through the Clean Development Mechanism (CDM). Therefore, the proposed project will be instrumental to explore and identify the requirements necessary to access the CDM-based global carbon markets and ensure that these requirements are taken
into account and fulfilled starting from the design and implementation of plans to develop, manage, utilize and conserve plantations of cactus pear on the degraded and other areas. Provisions will also be made in the project to support the local communities if and when they plan to access the global carbon markets.

3.10 Establishment of cactus pear plantations to produce cochineal dye

NB: This project component will be undertaken only after farmers and administrative personnel of Tigray region and in Yemen in Western (region around Hajjah), Southern (region around At Turbah, Al Hugariah district, south of Taizz) and Central Highlands (region around Sana’a) have accepted it.

Tigray region has proven its potential in cochineal production and management and practiced exporting of few products so far. This could be an excellent indicator for the need to further develop and scale-up the product. Hence, cochineal will be the biggest market opportunity for smallholder farmers and women in the region. So far, Food Safe Ethiopia has been involved in training 500 out-growers in partnership with the German Development Agency (GTZ) to farm cochineal.

Cochineal-carminic acid is also used as coloring agent for several food stuffs, (e.g. Italian aperitif Campari), beverages and cosmetics, which is natural and healthy. About 130,000 adult female insects produce 1 kg of the red dye. Growing of Cactus to support cochineal industries requires about 25,000 ha of land worldwide.

The Chilean conglomerate working in Tigray has started to supply carmine to local companies. The interest that has been shown by the Mexican company ALTECSA to establish a carmine extraction/processing factory in Tigray is also a good opportunity of cochineal production.

However, due to mismanagement of Cochineal insect production the majority of cactus plant in the mountain and around homestead is highly infested by insect. Farmers and government body are highly discouraged and became out of control, large area of cactus vegetation are seriously affected and even start drying. From the field observation we noticed that if there is a way to rear this beneficial insect
under controlled environment and in highly degraded lands, it would be the greatest opportunity for disadvantaged farm households due to environmental stresses. Consequently, the implementation of Cochineal dye production plant will be developed when the relevant stakeholders accepted the realization of this project component.

### 3.11 Research and Development

GAFEIAS scientific team will undertake research for development (R4D) to enhance productivity of cactus plantation in a drought affected degraded drylands of the project locations. Sustainable agriculture development will be assured through the application of bio-fertilizations (mycorrhizal mixture with rhizobial nitrogen fixing bacteria), in this regard the potential of indigenous soil microorganisms will be investigated. The R4D will be conducted in collaboration of Helmholtz Centre for Environmental Research-UFZ, Department of Soil Ecology, Germany; Boku, Institute of Forest Ecology, Austria and University of Pennsylvania. The bio-fertilization technology with indigenous soil microorganisms will have a win-win-win situation, through biodiversity conservation, reduction of environmental pollution due to chemical fertilizers, which even the most expensive agricultural inputs and providing healthy and affordable agricultural products for the poor rural communities.

Moreover, analysis and formulation of cactus-based nutraceuticals, nutritional food and drink product and other bioactive compounds will be conducted in collaboration with ICC (International Association for Cereal Sciences and Technology), Vienna, Austria; Addis Ababa University, Food Science and Nutrition Program and Department of Food Engineering, Ethiopia; and Pennsylvania State University, College of Agriculture, Department of Food Sciences. Product importance for personal hygiene, and cosmetic products, baby foods, hydration and energy drinks, animal nutrition and feed products, such as, fish feed and fodder, will be given special consideration.
4. Collaboration and Networking

GAFÉIAS established a strong cooperation with EPA, MoI, Mekele University-College of Dryland Agriculture and Natural Resources Management (MU-CDANRM), Tigray National Agricultural Research Institute (TARI), Addis Ababa University-Life Sciences Faculty (AAU-LSF), Wondo Genet College of Forestry and Natural Resources (WGCF-NR), Bahir Dar University, College of Agriculture and Environmental Sciences (BDU-CARS); Amhara National Regional Agricultural Research Institute (ARARI); FAO; GAFÉIAS; BOKU; ICC; University of California Los Angeles-Department of Ecology and Evolutionary Biology (UCL-DEEB); University of Botswana (UB) Okavango Research Institute (ORI). For further information visit www.gafeias.org

5. Strategic alliances with women and youth cooperatives

The private company will provide quality control guidelines and technical supports to cooperatives. On the other hand the cooperatives will also be expected to provide quality fresh and semi processed products to the private company on time. This interaction will be supported by the relevant government institutions such as, Investment Agency and Ministry of Industry, to avoid conflicts and maintain sustainability of the project.

6. Current and Past Experiences in Ethiopia

5.1 FAO activities and achievements

The project will seek to collaborate with FAO in order to avoid overlapping activities and it will focus mainly on commercialization of processed cactus pear products as well as promoting establishment of allied services among young potential entrepreneurs. The plantation management strategies established by FAO will be used as a guide to train farmers and other entrepreneurs for the new establishing cactus plantation in degraded semiarid areas of Eastern and Southern Tigray zones. Utilization of the collected Cactus varieties will be also used as a planting material
following verification of those varieties by FAO. For the future implementation of cactus pear project oral agreement has been made with Mr Giuseppe de Bac, FAO International Senior Advisor (SPA) for the projects in Ethiopia and with the Assistant FAO Representative in Ethiopia, Mr Hassen Ali. Consequently, GAFÉIAS-GAFEIAS cactus project will be implemented successfully with strong collaboration with FAO experts and officials. Giuseppe De Bac, FAO International Senior Advisor (SPA) for the projects in Ethiopia summarized the FAO activities in Tigray as follows:

5.1.1 Immediate objective

- To strengthen the technical capacity of communities in the project area in fruits and cactus pear production and management.

Output 1

- Farmers’ accessibility to the growers’ level model orchards increased.

Achievements:

- A cartoon manual for farmers has been finalized and printed; the manual focus on the main operation to be undertaken in order to produce quality cactus fruits

- Trainings of farmers has been conducted in different district on cactus pear fruit management, cluster farmers (average group of 25 persons) the land of whom is located around the project nurseries have been trained according to the calendar agreed with BoA. Last session of trainings have been undertaken in May and June 2011 respectively in:

  - Wukro district on 15 June 2011 for 60 farmers from Ganta Afeshum, Sasea Tasaeda Emba, Wukro and Hentalo Wajirat. The training focuses on cactus pear management and silage preparation for livestock feed. The hands on training was very constructive for the farmers who also visited Agula “cactus pear varieties collection block” and also carried out exercise on silage preparation from cactus leaves in one selected farmers plot around Wukro
Output 2

- The capacity of selected group of farmers strengthened in cactus production.

Achievements:

- A refreshment training has been conducted in June 2011 with the involvement of farmers already targeted in the previous years and with the involvement of new interested farmers (about fifty farmers selected (by BoA) in the area of Sekota Woreda (WagHamra) Machew and Adigrat (Tigray).

- Cartoon simple manuals with guidelines on crop management prepared in Tigrina and Amharic languages have been distributed to farmers. So far two trainings have been conducted with distribution of manuals, respectively in Wukro (Tigray) and N. Wollo (Kobbo).

Output 3

- 3,000 housewives and 1,000 students trained on cactus pear utilization

Achievements:

- The activity on cactus pear utilization is being conducted with the inclusion of practical training of students in selected schools of South Tigray and included in a more comprehensive programme of school gardening carried out in collaboration with WFP.

- The training has been conducted in collaboration with BoE and BoARD, from 5-11 July 2010. The demonstration/training, focused on cactus (nopalitos) food preparation and involved students, mothers and community representatives of 14 selected schools of South Tigray.

- Cactus pear (commonly known as “cactus pear”) marmalades and cactus homemade recipes have also been recommended to selected model women (Ms. Tsige, Ms. Zewdi) in order to facilitate promotion within the communities and improve cactus pear marketing opportunities.
• In the case of Ms. Tsige, the PM (project Management) decided that, thanks to her skill and effort in promoting the production of cactus pear recipes, assistance would have been granted for a contribution in establishing a cactus shop in Mekelle for promotion and selling of “cactus pear” products. The shop has been supplied (project support) with fridge, food mixer, and a small cooker; the shop rent is being subsidized by FAO project for an initial period of five months.

• Three women willing to promote cactus pear juice in the town of Woldia (Wollo) and Kobo have also been supported for the promotion of cactus pear fruits and processed produces. The project covered the expenses for the rent of a small kiosk (in Woldia), the purchase of fruit processing mixers and small items, like glasses and sieves.

5.1.2 Immediate Objective 2

• To improve post-harvest handling of cactus pear fruits and assist in promoting its marketing aspects.

Output 1

• Post-harvest handling of cactus pear fruits at the farmers’ level improved.

Achievements:

• Ad hoc harvesting tools (2500 hollow two side harvesting tools) were distributed to farmers in August 2008, a second batch of 500 improved harvesting tools has been manufactured (June-July 2010).

• Distribution of tools was partly conducted during the cactus farmers training, on 26-27 August 2010. On June 2011 distribution of tools together with protective gloves has been done. In Tigray (Wukro, 15 June) and North Wollo (Kobo) harvesting tools and special gloves for handling of fruits have been distributed to farmers during training.
Output 2

- Information system for cactus pear (*Opuntia ficus-indica*) production in the project area improved.

Achievements:

- Special software which enables to transmit wholesale weekly price of cactus pear fruits was prepared and installed in FAO office on 19 August 2010 by the IT expert. The software which serves as a pilot programme download data sent from the market places and is providing farmers with information on farm gate and market prices of different commodities, throughout SMS messages automatically sent by the central hard drive unit.

Output 3

- Linkages between traders and farmers strengthened.

Achievements:

- Linkage with traders for promotion of cactus pear and fruits is being strengthened. The project addressed the traders in contacting selected farmers for the supply of cactus pear and fruits, following a campaign of promotion of new introduced varieties and species of fruits in the markets of Addis Ababa.

- Regarding tropical fruit seedlings the farmers are responsible to inform DoA (Department of Agriculture) on the type of seedlings available for sell, so that the DoA will guide farmers in fixing prices and selling their seedlings.

- Regarding marketing of tropical fruits and cactus pear, FAO is facilitating the creation of linkage with fruit juice houses. In the case of the introduced temperate fruits, and only in the case of the farmers who are producing almonds, apricots and plums for the first year (farmers who previously accepted to carry out on farm trials with the new introduced species and varieties) the project team is engaged in facilitating linkages with markets/town shops. In this regard the farmer production, upon a special request, is totally purchased by FAO and given to shops in Mekelle town for display and promotion.
5.2  Cactus Pear Variety collection blocks established in Tigray Region

Three germplasm collection plots have been established in Agula and Wukro (Tigray) in 2008 and replicated in Dereka (Tigray) and Aloha (Wollo) in 2009. 42 local landraces and 4 selected varieties introduced from Mexico have been planted in the collection plots for evaluation. The performance of the varieties is being evaluated and collection of data is being analyzed (i.e. size of fruits, number of seeds/fruit, quality of fruits sugar contents of the fruits and PH and other characters).

With the financial support from UNIDO, the GAFÉIAS project team has been met FAO team members on November 21, 2011 in Mekelle, Tigray, Ethiopia and has been introduced to FAO activities in Tigray through a power point presentation about the FAO Cactus Pear Variety collection blocks and research results. The FAO project infrastructure has been described, literature exchanged and network partner recommended. Cactus production, processing and marketing challenges has been discussed. It has been decided to find a way how to continue the FAO project activities on cactus technology development and to ask for further negotiations and permissions with Giuseppe De Bac, FAO International Senior Advisor (SPA) for the projects in Ethiopia and the Assistant FAO Representative in Ethiopia, Mr. Hassen Ali. In this survey, both, FAO representatives and GAFÉIAS project team members are keen to focus on a continuation of the cactus oriented activities of FAO in Tigray. As soon as a hand over of the FAO project to a local research institution has been processed, GAFÉIAS co-operation with the respective institution will be established accordingly.

7. The target beneficiaries

The project will build on the achievements of FAO and, especially, target marginalized communities that otherwise have no or little means of breaking out of poverty and where land degradation is very much a threat to survival. The direct beneficiaries of the project include:
1. **Farmers’ cooperatives:**
   - The capacity of selected cooperative members will be upgraded in terms of processing equipment and technical/managerial skills, thus they will improve their livelihood. Trainings on Hazard Analysis Critical Points Control Point (HACCP) and a good manufacturing practice (GMP) will be given to for women and youth cooperatives.

2. **Existing small scale allied support industries:**
   - They will be upgraded in terms of technical and managerial skills and equipment. Trainings on Hazard Analysis Critical Points Control Point (HACCP) and a good manufacturing practice (GMP) will be given to small scale entrepreneurs.

3. **Young potential entrepreneurs (men and women):**
   - They will be assisted to establish their own support services in relation to cactus pear production, processing and marketing. Trainings on value addition and value chain development will be given for potential youth entrepreneurs.

**8. Alignment with national and international strategies and development goals**

The project is completely in line with the Growth and Transformation Plan (GTP), which is the national medium term strategic framework for the five-year period starting 2010. The vision outlined for the economic sector in the GTP is “to build an economy which has a modern and productive agricultural sector with enhanced technology and an industrial sector that plays a leading role in the economy; to sustain economic development and secure social justice; and, increase per capita income of citizens so that it reaches at the level of those in middle-income countries.”. Agro-Processing industries have been singled out as one of the sectors to receive special support under the GTP.

The project is also in line with the United Nations Development Assistance Framework (UNDAF), contributing to the achievement of outcome 1: Increased use by agricultural producers of improved institutional services, efficient marketing.
system, and appropriate technology and practices for sustainable increases in agricultural production and productivity by 2015 and outcome 2: By 2015, private sector-led Ethiopian manufacturing and service industries, especially small and medium enterprises, sustainably improved their competitiveness and employment creation potentials. The project will also directly contribute to Millennium Development Goals 1 (eradicate poverty), 3 (gender equality), 7 (environmental sustainability) and 8 (global partnership). Moreover, the project contributes to implement the UN Conventions on Climate Change and to Combat Desertification.

9. **Project Objective**

To develop sustainable agriculture in the arid regions for sustainable livelihood and environmental conservations

9.1 **The specific objectives of the project are:**

1. Establishing cooperatives of different groups, e.g. farmers, women, and youth ,
2. Physical and material capacity building of farmers, youth and women groups, and other relevant experts
3. Establish and develop profitable value chains of cactus pear products
4. Develop and implement projects targeting the rapidly emerging international carbon markets through the expansion of cactus pear plantations on degraded landscapes

Carry out R4D on bio-fertilization with soil microorganisms, species diversity analysis of OFI and analysis of OFI’s for functional uses

10. **Expected outcomes**

The following are the envisaged outcomes from the successful implementation of the proposed project.

**Outcome 1:** Improved livelihood of rural communities, with special emphasis on women, through the setup of associations and cooperatives

**Indicator:** Income levels targeted groups
Outcome 2: Diversified use of cactus pear for production of nutritional food (e.g., baby foods), livestock fodder, fish feed, energy drinks, health drinks, liquor, concentrate, extracts and powders

Indicator: New products, and new recipe

Outcome 3: Increase in the quality and quantity of processed cactus-based food and feed products available in the market

Indicator: The amount of tonnes / liters of different food, feed and other cactus based products supplied to markets (Baseline: backyard jam cooking and similar low scale activities)

Outcome 4: Supply capacity for cactus pears and pads in northern Ethiopia and Yemen, Western (region around Hajjah), Southern (region around At Turbah, Al Hugariah district, south of Taizz) and Central Highlands (region around Sana’a, developed through a value chain approach

Indicator: Sustainable and profitable market established

Outcome 5: Degraded areas are increasingly being used for commercial cactus plantations through the application of bio-fertilization

Indicator: Annual increase in hectares of formerly degraded land converted to cactus production area, production of organic food in European and American standard

11. Outputs and activities

Output 1: Supply capacity for cactus pear fruits and pads in the arid regions

The project will revitalize and strengthen the existing cooperatives and organize as many rural and urban cooperatives of farmers/city dwellers, women and youth as feasible to be engaged at the various levels of the value chain. Two major challenges of cactus pear growing local communities in Tigray are post-harvest loss of, especially the fruit (estimated at > 60% in some areas), and absence of value adding
initiatives. The project will establish a number of collection centers, establish a more efficient transport system and equip cooperatives with proper tools in order to strengthen the supply chain and to reduce post harvest losses. Cooperation with Mekelle City Centre of Trade and Industry will be sought in order to link up with existing companies that can provide services along the value chain development.

**Output 2: Cactus pear processing plant established**

One of the interventions in the proposed project will be to establish processing capacity to manufacture a stable supply of marketable cactus pear-based products. The industrial transformation and packaging of fruits and pads into various high-quality food commodities will not only increase the shelf life but also increase the marketability both domestic and international markets. The processing center will have proper infrastructure and equipment for treatment of fresh fruits and pads such as a de-spining, washing and peeling. Equipment for drying, milling, juice extraction, boiling, cooling and similar will be installed together with suitable packaging and storage solutions for processed and semi-processed food products such as beverages, jam, flour and different types of candy based on dried fruits. In order to secure a cheap energy source the processing center will be equipped with a biodigester using cactus pear by-products as feedstock. The exact set-up of the processing center will be determined after a feasibility study. The project will introduce the best practices of processing cactus pear in order to ensure the highest quality of the end products.

**Output 3: Market channels for cactus pear products established**

The project will promote cactus pear products aggressively in the region as well as in Addis Ababa and other urban centers of Ethiopia and Yemen in order to sensitize the population and develop a local demand for cactus pear products. The project will assist in the identification of national and international (niche) markets for the different cactus pear products locally, nationally, regionally and internationally. The project will also identify potential agents, distributors, fruit packers, wholesalers, retailers and industrial customers, in order to achieve access to identified markets. The project will aim at creating a highly appreciated brand
image of the cactus pear products from Ethiopia in the international consumer markets.

**Output 4: Rehabilitation and economic potential of degraded land demonstrated**

GAFÉIAS will partner with suitable institutions and NGOs, and explore the opportunities of obtaining degraded land and in collaboration with the Environmental Protection Agency (EPA) and other relevant authorities explore the opportunities of rehabilitate the land through cactus pear plantations. The project will involve vulnerable groups, such as unemployed youth without access to land and women groups, and support them to become the owners and administrators of the plantations and link them to the processing center so that they will have a secure outlet for their products. The project will produce manuals so that successful models easily can be replicated in the region by the local authorities. Restoring degraded land and at the same time utilizing it for economic activity could have substantial positive economic and environmental impact in the region and the project will also explore the potential for global carbon markets.

The proposed project activities keyed under their corresponding expected outputs and the institution(s)/individual(s) that will be responsible for their implementation are presented in Table 1.

**Table 1. Project activities keyed under their respective outputs**

<table>
<thead>
<tr>
<th>Outputs and Activities</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output 1</strong>: Stakeholders at various levels on the importance, production, processing and marketing of products of cactus pear are aware and well trained</td>
<td>GAFEIAS, Ministry of Industry, Ethiopian Commodity Exchange (ECEX),</td>
</tr>
<tr>
<td>Activity</td>
<td></td>
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<tr>
<td>1.1 Prepare and deliver relevant and properly packaged series of awareness creation and training programmes on all aspects and the crucial importance of cactus pear, its various products and the available and potential markets to stakeholders at various levels</td>
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<tr>
<td>1.2 Organizing youths/women entrepreneurs into cooperatives</td>
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</table>
1.3 Strengthen the capacity of government and social institutions providing training and support in the establishment and management of cooperatives
1.4 Carry out the training of farmers and members of cooperative in management, harvesting, transporting and storage of fresh cactus pears/cladodes as well as in marketing of fresh and processed cactus products
1.5 Establishment of office construction

**Output 2:** Diversified high quality processed products (e.g. jam/marmalades, juice, dried/dehydrated products, seed oil, silage in combination with other protein rich fodders etc.) are established from exiting *Opuntia* plantation; species are selected according to their functional uses (fruits, seeds and cladodes production) for enhancing their productivity on degraded lands allocated for unemployed youth groups

**GAFEIAS, ICC, AAU, Penn State**

### Activities

2.1 Conduct a feasibility study to establish the location and capacity of the processing centre (full structure, staffing), the products it should process complete with a cost analysis and priority markets
2.2 Rehabilitate civil construction to host the processing centre, including warehouse capacity
2.3 Equip the centre with suitable processing and packaging equipment for cactus based products
2.4 Equip the centre with a bio-digester for methane production for industrial heat
2.5 Provision of training for the plant managers, processing personnel and youth/women entrepreneurs in management of food processing plant, processing of different cactus pear and cladodes products (e.g. jam, juice, dried products, seed oil, flower, etc.) as well as in the operation and maintenance of the equipment
2.6 Carry out extensive training in GMP/HACCP and quality management for plant managers, processing personnel and youth/women entrepreneurs
2.7 Prepare a draft directory of suppliers of ingredients, packaging materials and equipment in Ethiopia
2.8 Designing packaging materials (labels, plastic bags, glass jars, cartons, etc.) for different cactus pear products
2.9 Carry out training of farmers and members of cooperative in beekeeping and honey processing
2.10 Participatory based *Opuntia* variety selection and characterization for their adaptation on drought prone areas with poor soils condition of the semiarid zones

**Output 3:** Rehabilitation and economic potential of degraded land demonstrated and atmospheric carbon capturing is enhanced

**GAFEIAS, NUTRAFRICA, EPA, BoARD**
**Activities:**

3.1 Secure degraded land for vulnerable groups (unemployed youth, women groups) from the Government and develop small scale commercial cactus plantations with these group based on **output 2: Activity 2.7** findings

3.2 Application of beneficial microorganisms (*Arbuscular Mycorrhiza Fungi*) as bio-fertiliser to enhancing Bio-cactus pear productivity under environmental stresses

3.3 Develop and implement projects targeting the rapidly emerging international carbon markets through the expansion of cactus pear plantations on degraded landscapes

3.4 Develop capacity of local communities as well as relevant government and non-government organizations to access the global carbon markets / financing

**Output 4:** Local, national, regional and international market are assessed and market channel for processed cactus products and cactus honey are established

**Activities:**

4.1 Assist the SMEs in the preparation of their products for presentation at local, regional and international trade fair

4.2 Train the plant managers and sales personnel in the presentation of products and marketing

4.3 Develop market outlets and linkages to retailers / wholesalers for processed and semi-processed cactus related products

4.4 Identify potential niches for the selected sub-sectors/products in the domestic, regional and/or international markets

4.5 Explore the above market niches and identify the marketing modalities, the distributions channels and the requirements in terms of quantity and quality

4.6 Identify potential partners and types of finished cactus pear products and establish MOU

4.7 Develop promotional material for processed cactus based products

4.8 Micro-enterprises established to support the production, processing and marketing of fresh and processed products

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GAFEIAS, NUTRAFRICA, ECEX,
Figure 1: Value chain flowchart of fresh and processed products of cactus pear
## 12. **Timeline and the activities**

**Table 2:** Planned proposed project activities with the corresponding implementation timelines presented in quarters of the three years

<table>
<thead>
<tr>
<th>Phases</th>
<th>First phase of the project</th>
<th>Second phase of the project</th>
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<tbody>
<tr>
<td>Activity Milestone</td>
<td>1.1 Trainings and awareness creation on the various use of cactus pear, its various products and its commercial value for stakeholders at various levels</td>
<td>2.1 Conduct a feasibility study to establish pilot processing centre</td>
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<tr>
<td></td>
<td>1.2 Organizing youths/women entrepreneurs into cooperatives</td>
<td>2.2 Rehabilitate civil construction to host the processing centre, including warehouse capacity</td>
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<td></td>
<td>1.3 Strengthen the capacity of government and social institutions providing training and support for the sustainability of established cooperatives</td>
<td>2.3 Equip the centre with suitable processing and packaging equipment for cactus based products</td>
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<td>1.4 Carry out the training of farmers and members of cooperative in management, harvesting, transporting and storage of fresh cactus pears/cladodes as well as in marketing of fresh and processed cactus products</td>
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<td>1.5 Establishment of office infrastructure</td>
<td>2.5 Provision of training for the plant managers, processing personnel and youth/women entrepreneurs in management of food processing plant, processing of different cactus pear and cladodes products (e.g. jam, juice, dried products, seed oil, flower, etc.) as well as in the operation and maintenance of the equipment</td>
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<tr>
<td></td>
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<thead>
<tr>
<th>Phases</th>
<th>Four yours of project activity plan (quarterly)</th>
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<tr>
<td></td>
<td>Year 1</td>
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<tr>
<td>Phases</td>
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<tr>
<td>First phase of the project</td>
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<td>Second phase of the project</td>
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<th>Equipment in Ethiopia</th>
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<td>2.10 Participatory based <em>Opuntia</em> variety selection and characterization for their adaptation on drought prone areas with poor soils condition of the semi-arid zones</td>
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<tr>
<th>Third phase of the project</th>
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<tbody>
<tr>
<td>3.1 Secure degraded land for vulnerable groups</td>
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<tr>
<td>3.2 Application of beneficial microorganisms as organic fertilizer for enhancing Bio-cactus pear production</td>
</tr>
<tr>
<td>3.3 Expansion of cactus plantation on a degraded land to meet the rapidly emerging international carbon markets</td>
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<tr>
<td>3.4 Develop capacity of local communities as well as relevant government and non-government organizations to access the global carbon markets / financing</td>
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<tr>
<td>4.1 Assist the SMEs in the preparation of their products for presentation at local, regional and international trade fair</td>
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<td>4.7 Develop promotional material for processed cactus based products</td>
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<td>4.8 Micro-enterprises established to support the production, processing and marketing of fresh and processed products</td>
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| Project evaluation |
13. **Risks**

Limited access to local, national and international markets for fresh and processed cactus pear products, when implementation of existing land use policies are not in place, lacking appropriate institutional arrangements, lacking well established infrastructures (water, electricity, road, etc), full and committed involvement of targeted groups are not met, if there is no enough budget available, if there is epidemic pest and disease affecting the growth of cactus pear exist; the above mentioned objectives might not be achieved.

14. **Inputs**

14.1 **Counterpart inputs**

Counterpart institutions will support the project in policy formulation and implementation, in providing marginal lands for youth and women associations for further development of Cactus-pear plantations and processing centres establishment, facilitating market channels, technical supports for Development Agents at district level (DAs), farmers and private entrepreneurs, in providing credit services and close monitoring of the project

**GAFÉIAS inputs**

GAFÉIAS will coordinate project activities at the top level in collaboration with MoI and Agricultural Research Institutes, it also implementing major activities and negotiation with national and international consultants, evaluating the project progress and regulating project action plan. Terminal report will be organized and reporting for funding organizations. In general, GAFEIAS is responsible in project designing, implementation, evaluation and impact assessment.
Specific tasks to be accomplished by GAFÉIAS project team

(1) International Consultant: GAFÉIAS Project Coordinator will take the responsibility to lead the project at the top level and design strategies and establish network with relevant development oriented international organizations

(2) GAFÉIAS project coordinator creates an opportunity to link the national project leader and cooperative leaders with an international market and provide the available advanced production and processing technologies

(3) Closely follow and ensure whether the on-going project implementation achieves the targeted objectives and organize quarter progress report and presented for the funding organization

(4) GAFÉIAS project coordinator will screen best cactus varieties according to their functional uses and develop manuals for plantation and management, harvesting and post-harvest management

(5) GAFÉIAS project coordinator will identify compatible crops with cactus pear plantation and design sustainable agricultural development systems, thus diversify source of income for local community

(6) GAFÉIAS project coordinator will work closely with the national project leader and solve challenges and develop strategies to solve interest conflicts within the cooperatives

(7) GAFÉIAS coordinator will organize international study tours for cooperative members and extension agents, trainings for experts and organizing national and international workshops, and linkage with international research groups working on cactus pear improvement and its divers uses for its industrial importance

(8) GAFÉIAS administration office take the responsibility on finance management and purchase of necessary imputes for project implementations, Office infrastructure and construction, contracting
project components signing agreements with other companies or organizations in relation to the project

(9) GAFÉIAS administration office will facilitate the provision of international cactus product market and establish communication platform between relevant stakeholders

National staff

National Project Coordinator (Mekelle Based, Full-time)

The national project coordinator (NPC) will take part in coordinating different project activities in collaboration with the relevant government institutes. The NPC will undertake the following activities:

(10) Leading the project team and coordinating the cactus pear project,

(11) Develops a detailed project schedule which includes administrative tasks and all activities involved in the project,

(12) Implementing the agreed action plan to the agreed standards and deadlines,

(13) Exchange of information with the GAFÉIAS-PM and GAFÉIAS 6 - Environment and Food Security Directorate (GAFÉIAS-EFSD) on all project-related matters,

(14) Ensuring the effective preparation and delivery of all project achievements and meetings and production of all necessary documentation,

(15) Taking responsibility for the effective flow of information between team members, participants in project activities, partner government institutions, GAFÉIAS-PM and GAFÉIAS-EFSD,

GAFÉIAS: Global Association for Environmental Investments and Sustainability of Economic, Social and Environmental Spheres
(16) On-going evaluation of project activity and reporting on project progress to the GAFÉIAS branch office in Ethiopia, the GAFÉIAS head quarter and GAFÉIAS-EFSD,

(17) Organizing training workshops and awareness creations for policy makers.

(18) Compile summary documents, e.g. product development plan, management summary, marketing networks and working environment

(19) Submission of the final results of the project to the GAFÉIAS-PM and GAFÉIAS-EFSD,

The project coordinator therefore must has experience in development project planning and knowledge of the working languages; Amharic and English

Sub-contracts

Sub-contracts will be offered for the construction and installation of processing units and also other infrastructure developments, such as, water and electricity. Moreover, trainings for farmers and extension agents will be subcontracted. The constructors will be recruited from the hosting country through normal GAFÉIAS procurement procedures. However, some activities, such as installation of renewable energy sources (solar energy, biogas-digester, etc.), advanced trainings on hygienic food processing and building the technical competency of small and medium youth and women entrepreneurs, and project evaluation might be contracted for international consultants based on the decision from GAFÉIAS PM (GAFÉIAS-Project Manager) in collaboration with GAFÉIAS.

Training

Trainings will be given for different actors of the project in different areas,

(1) Harvesting techniques, post-harvest handling, processing, and market network establishment, cooperative management will be given for youth and women cooperatives.

(2) Training workshops in value addition, value chain development, IT and environmental aspects will be given to member of cooperative, private
entrepreneurs, experts from Bureau of Agriculture and Rural Development (BoARD), Environmental Protection Authority (EPA), Bureau of Trade and Industry (BoTI)

(3) Study tours will be organized for selected member of cooperatives, national and international project coordinators, extension agents, head of the district administration, active private entrepreneurs and relevant experts and researchers from BoARD, BoTI, TARI7, MU8, GAFÉIAS and GAFÉIAS; in other experienced countries in cactus pear production, management, processing and marketing (e.g., Mexico, Italy, Morocco, and California (UCLA Department of Ecology and Evolutionary Biology)

(4) Awareness creation workshops will be organized for policy makers and local administration staffs

Equipment and supplies

Harvesting tools, equipment for transportation of collected plant parts; weighing scales, protection clothes and safety shoes, clothes for hygienic processes and other cleaning materials, mobile cookers, input and product storage facilities, integrated processing units including; (1) receiving, washing, spines removing, grading, preparation and sorting machine (this machine delivers fruits to the plant and transferred to flumes or conveyers through manual, mechanical or hydraulic means. Fruits are then conveyed to the washing and sorting area. Field material is removed from the fruit that is then sorted by manual or electronic system); (2) water evaporation machine (the machine removes water from the juice or jam stream to concentrate the product, hence the highest quality of the product can be achieved by removing water, preserving the color and the organoleptic properties of the fresh fruit); and (3) aseptic sterilizer and filling and packing machine (In a closed aseptic system the fruit is heated, held at temperature to obtain commercial sterility, and aseptically cooled to ambient temperature). GPS, digital camera, office equipment (computer, printer, stationeries’ and other office tools and equipment) will be required.

7 Tigray Agricultural Research Institute
8 Mekelle University
15. **Budget**

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit cost</th>
<th>units</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Technical Advisor</td>
<td>15,000</td>
<td>24</td>
<td>360,000</td>
</tr>
<tr>
<td>International experts</td>
<td>10,000</td>
<td>5</td>
<td>50,000</td>
</tr>
<tr>
<td>Support Personnel (driver, secretary)</td>
<td>600</td>
<td>72</td>
<td>43,200</td>
</tr>
<tr>
<td>Project travel</td>
<td>50,000</td>
<td>1</td>
<td>50,000</td>
</tr>
<tr>
<td>GAFÉIAS staff travel</td>
<td>4,000</td>
<td>6</td>
<td>24,000</td>
</tr>
<tr>
<td>National Project Coordinator</td>
<td>3,000</td>
<td>36</td>
<td>108,000</td>
</tr>
<tr>
<td>National experts</td>
<td>3,000</td>
<td>18</td>
<td>54,000</td>
</tr>
<tr>
<td>Subcontract feasibility study processing</td>
<td>50,000</td>
<td>1</td>
<td>50,000</td>
</tr>
<tr>
<td>Subcontract civil construction</td>
<td>250,000</td>
<td>1</td>
<td>250,000</td>
</tr>
<tr>
<td>Subcontract degraded land</td>
<td>250,000</td>
<td>1</td>
<td>250,000</td>
</tr>
<tr>
<td>Study Tours</td>
<td>20,000</td>
<td>1</td>
<td>20,000</td>
</tr>
<tr>
<td>In-service training</td>
<td>125,000</td>
<td>1</td>
<td>125,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>750,000</td>
<td>1</td>
<td>750,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>50,000</td>
<td>1</td>
<td>50,000</td>
</tr>
<tr>
<td>Evaluation</td>
<td>30,000</td>
<td>1</td>
<td>30,000</td>
</tr>
<tr>
<td>subtotal</td>
<td></td>
<td></td>
<td>2,214,200</td>
</tr>
<tr>
<td>Administration cost (13%)</td>
<td></td>
<td></td>
<td>287,846</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2,502,046</td>
</tr>
</tbody>
</table>

16. **Monitoring, reporting and evaluation**

The project will be executed by GAFÉIAS in collaboration with NutrAfrica and local and international collaborators.

A Project Manager (PM) will oversee the overall implementation of the project. A Project Coordination Unit (PCU) will also be established. This unit will include a Chief Technical Advisor (2/3-time), a National Project Coordinator (full-time),
supporting by an Administrative Assistant (full-time) who will all be responsible to the PM. International and national consultants will be recruited on short-term contracts to address specific activities. The PCU will be responsible for overall day-to-day co-ordination and supervision of field activities, including effective linkages between the project and the beneficiaries and other on-going project and programmes, ensuring an effective monitoring and evaluation system of all activities.

A Project Steering Committee (PSC) will be chaired by the Minister of Industry. It will include representatives of all stakeholders. The main functions and responsibilities of the PSC will be to: (i) advise the project on strategic directions of support activities to be provided; (ii) ensure the effective cooperation between all involved stakeholders; and (iii) advise the effectiveness of the ongoing activities, including the progress towards achieving the planned outputs, review and approve an annual work plan. The PSC will help achieve greater co-ordination and cooperation among stakeholders and will ensure national ownership and sustainability of the project planned activities. The PSC will hold bi-annual meetings and more frequently if the situation requires. The Project Coordinating Unit (PCU) will act as the secretariat.

The CTA will prepare bi-annual progress reports on project activities detailing progress achieved towards meeting the stated outputs, the problems and constraints, and recommendations for correcting them, plus a detailed work plan for the following period. The report will be discussed in the regular PSC meetings and corrective actions will be taken. Each report will be sent to the donor with copies to the national counterparts for their information and appropriate actions. During the last three months of the project, the CTA shall prepare and submit to the counterpart and to the donor a terminal report for approval. This terminal report will assess, in a concise manner, the extent to which the project’s scheduled activities have been carried-out, the outputs produced, and the progress towards achieving its objectives. It will also present recommendations for any future follow-up action arising out of the project.
Monitoring of the project activities will include data collection and analysis arrangements, baseline information, programme of work and budget expenditures. Special attention will be given to the participation of the beneficiaries in the monitoring process. Monitoring modalities will be agreed upon by the PCU and the experts during the first months of the project and the on-going results will serve as a management tool to ensure effective and efficient project operation.
### Logical Framework

<table>
<thead>
<tr>
<th>Development goal</th>
<th>Intervention logic</th>
<th>Objectively verifiable indicators</th>
<th>Sources of verification</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome(s)</strong></td>
<td>• Promote commercialization of marginal land through innovative cactus plantation management, thereby ensuring food security well as mitigation of land degradation and ensuing desertification in northern Ethiopia</td>
<td>Field survey and Annual growth of GDP in targeted regions</td>
<td>The survey report</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Degraded areas are increasingly being used for commercial cactus plantations</td>
<td>• Total degraded land dedicated to cactus farming</td>
<td>• Reports from MoARD, MoT and EPA</td>
<td>The Government remains committed to support the cactus initiative and the policy framework remains supportive for expanding and upgrading farmer’s investment on cactus plantation technology and facilitated export of products</td>
</tr>
<tr>
<td></td>
<td>• Improved livelihood of rural communities, with special emphasis on women, through the setup of associations and cooperatives</td>
<td>• Cactus products are promoted at different levels</td>
<td>• Impact assessment report by GAFEIAS and GAFÉIAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase in the quality and quantity of processed cactus-based food and feed products available in the market</td>
<td>• The livelihood improvement of the rural poor engaged in cactus production</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output 1</strong></td>
<td>• Stakeholders at various levels on the importance, production, processing and marketing of products of cactus pear are aware and well trained</td>
<td>• At least 50 meetings are held with stakeholders in different districts and over 100 trainers trained for the dissemination of information.</td>
<td>• Reports on the meetings and trainings manuals</td>
<td>Stakeholders are receptive to change, the district administrations are supportive</td>
</tr>
</tbody>
</table>

<p>| | | | | |
|                  | | | | |</p>
<table>
<thead>
<tr>
<th>Activities</th>
<th>1.1 Trainings and awareness creation on the various use of cactus pear, its various products and its commercial value for stakeholders at various levels</th>
<th>• Manuals and guide are produced and used appropriately. At least 50 trainers are trained within one year.</th>
<th>• Report and list of participants</th>
<th>• Selected trainers remain committed • Targeted stakeholders are remaining committed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Organize selected groups into cooperatives, production units and associations</td>
<td>• Cooperatives at different level, such as, production and collection, processors and marketing are established • At least 5 cooperatives are established within 6 months</td>
<td>• Existing successful cooperatives • Reports from GAFEIAS, GAFÉIAS • Registration of the cooperative at the relevant zonal bureaus • Report of support from government Authorities</td>
<td>• Selected members remain committed • BoARD are supportive</td>
<td></td>
</tr>
<tr>
<td>1.3 Strengthen the capacity of government and social institutions providing training and support for the sustainability of established cooperatives</td>
<td>• Training held and national expertise provide support services</td>
<td>• Report from Government institutes and GAFEIAS-GAFÉIAS</td>
<td>• Government’s officials are committed</td>
<td></td>
</tr>
<tr>
<td>1.4 Train and equip target groups on post-harvest handling and preservation and marketing</td>
<td>• Cooperatives engaged in at different chain of production are technically able to</td>
<td>• Field visit</td>
<td>• Targeted trainees remain committed.</td>
<td></td>
</tr>
<tr>
<td>Output 2</td>
<td>Manage cactus production and marketing self-reliantly</td>
<td>Activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Pilot cactus processing plant established, best varieties of <em>Opuntia</em> are selected for afforestation of degraded lands</td>
<td>• High quality and quantity of processed cactus products are enhanced</td>
<td>2.1 Conduct a feasibility study to establish pilot processing centre</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Production and sales records</td>
<td>2.2 Rehabilitate civil construction to host the processing centre, including warehouse capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Government’s policy on the promotion of the production and processing of prickly pear products remains unchanged</td>
<td>2.3 Equip the centre with suitable processing and packaging equipment for cactus based products</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. reports, supplier invoices, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Government’s readiness to provide incentives and land allocation to cactus farmers remains unchanged</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3 Equip the centre with suitable processing and packaging equipment for cactus based products

• Three collecting centres with good facilities are established
• Targeted member of the cooperatives are equipped with the necessary tools and equipment
• Visiting established collection centres and cooperatives
• Report from the relevant government institutes

Government’s readiness to provide incentives and land allocation to cactus farmers remains unchanged
<table>
<thead>
<tr>
<th>Output 3</th>
<th>• Local, national, regional and international market and market channel for processed cactus pear</th>
<th>• Market assessment report</th>
<th>• Market infrastructure is sufficient for marketing of the</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 Carry out extensive training in GMP/HACCP and quality management for plant managers, processing personnel and youth/women entrepreneurs</td>
<td>• At least 20 personnel (5 from each centres) are trained, HACCP manual prepared and implemented at the pilot centres.</td>
<td>• Training manual</td>
<td>• HACCP is recognized by the Ethiopian Bureau of Standards (EBS).</td>
</tr>
<tr>
<td>2.5 Prepare a draft directory of suppliers of ingredients, packaging materials and equipment</td>
<td>• Directory of suppliers prepared and published</td>
<td>• The directory itself</td>
<td>• Suppliers provide necessary information</td>
</tr>
<tr>
<td>2.6 Designing packaging materials (labels, plastic bags, glass jars, cartons, etc.) for different cactus pear products</td>
<td>• Standardized packaging materials for various processed products</td>
<td>• Packed products at the supermarkets</td>
<td>• Government’s policy on the importation of packaging materials for processed products remains unchanged</td>
</tr>
<tr>
<td>2.7 Carry out the training of farmers and members of cooperative in management, harvesting, transporting and storage of fresh cactus pears/cladodes as well as in marketing of fresh and processed cactus products.</td>
<td>• At least 60 youth/women entrepreneurs and 100 farmers are trained</td>
<td>• Training manual and report</td>
<td>• Farmers remain committed</td>
</tr>
<tr>
<td>2.8 Carry out training of farmers and members of cooperative in beekeeping and honey processing</td>
<td>• Training conducted and farmers are equipped with modern hives and processing equipment</td>
<td>• Training manual and report • The beehive itself</td>
<td>• Farmers remain committed</td>
</tr>
</tbody>
</table>
products and cactus honey functional are identified

<table>
<thead>
<tr>
<th>Activities</th>
<th>Processed products and cactus flower honey are presented in at least 4 regional and international trade fairs</th>
<th>Confirmation of registration and attendance; and sales sheets</th>
<th>Government’s policy on the promotion of export markets for agro-products is implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Assist the SMEs in the preparation of their products for presentation at local, regional and international trade fair</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>1.2 Train the plant managers and sales personnel in the presentation of products and marketing.</td>
<td>• At least 10 sales staff trained and quality of the presentation of products improved</td>
<td>• Training manual and report</td>
<td>• Quality of processed products meets international standards</td>
</tr>
<tr>
<td>1.3 Establish sales outlets for the products in Mekelle, Adigrat and Addis Ababa</td>
<td>• At least two sales outlets (Mekelle and Adigrat) and 3 in Addis Ababa established</td>
<td>• Sales report sheet</td>
<td>• Quality and quantity of processed products balanced with the markets demand</td>
</tr>
<tr>
<td>1.4 Assess the market to identify potential niches for the selected sub-sectors/products in the domestic, regional and/or international markets</td>
<td>• Niches identified and new products developed to meet the requirements of the market.</td>
<td>• Assessment report</td>
<td>• Government’s policy on export of processed products remains unchanged</td>
</tr>
<tr>
<td>1.5 Explore the above market niches and identify the marketing modalities, the distributions channels and the requirements in</td>
<td>• At least four distribution channels identified.</td>
<td>• Summary report</td>
<td>• Government’s support in accessing information remains unchanged</td>
</tr>
</tbody>
</table>
### 1.6 Identify potential partners and types of finished cactus pear products required by the market
- Potential partners and types of finished products identified
- Summary report
- Government’s policy on export of processed products remains unchanged.

### 1.7 Promotion activities undertaken for marketing of processed cactus and honey products
- Processed cactus products available in local / regional markets / international market
- Field reports
- Processed cactus products are received well by the consumers and gain popularity

### 1.8 Micro-enterprises established to support the production, processing and marketing of fresh and processed products
- 60% of the trained youth entrepreneurs (men and women) start their own business independently
- Field reports
- Cooperatives have access to agricultural implements, maintenance services for agricultural machinery and transport services
- Processing equipment can be sourced locally for entrepreneurs who want to expand / start up their business.
Annex 1. General schematic representation for processing of prickly pear parts
Annex 2. Potential flow diagram for prickly pear fruit and seed processing
Annex 3. Flow diagram of juice processing

Prickly pear fruit

Reception/washing

Peeling

Juice extraction

Blending/Mixing

Water, sugar, lemon juice

Pasteurization

Filling

Sterilized cans/bottles

Sealing

Cooling

Labeling

Packaging

Marketing
Annex 4. Flow diagram of Jam processing

1. Prickly pear fruit
2. Reception/washing
3. Peeling
4. Pulping
5. Cooking
6. Finishing at 68 to 70% TSS
7. Hot Filling
8. Sugar and pectin
9. Sterilized cans/glass jars
10. Cooling
11. Labeling
12. Packaging
13. Marketing
Annex 5.  **Flow diagram of dried/dehydrated prickly pears fruits processing**
## Annex 6. Basic Equipment for fruit juice and jam processing

<table>
<thead>
<tr>
<th>Processing stage</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport of fruits</td>
<td>• Casetas (wooden crates)</td>
</tr>
<tr>
<td>Reception/washing</td>
<td>• Weighing scales (0-50 kg)</td>
</tr>
<tr>
<td></td>
<td>• Hand refractometer (0-90° Brix)</td>
</tr>
<tr>
<td></td>
<td>• Washing basins</td>
</tr>
<tr>
<td>Peeling and Crushing</td>
<td>• Stainless steel table</td>
</tr>
<tr>
<td></td>
<td>• Stainless steel knives</td>
</tr>
<tr>
<td>Juice extraction</td>
<td>• Fruit juice extractor</td>
</tr>
<tr>
<td></td>
<td>• Manual fruit press</td>
</tr>
<tr>
<td>Pasteurization and cooling</td>
<td>• Pasteurizer (boiling pans/pasteurizer)</td>
</tr>
<tr>
<td></td>
<td>• Bottle cooler</td>
</tr>
<tr>
<td>Filling</td>
<td>• Juice filling (semi-Automatic filler)</td>
</tr>
<tr>
<td></td>
<td>• Manuel bottle filler</td>
</tr>
<tr>
<td></td>
<td>• Hand operated capping device (capper)</td>
</tr>
<tr>
<td>Others</td>
<td>• Workers protective gear</td>
</tr>
<tr>
<td></td>
<td>o Overalls/Aprons</td>
</tr>
<tr>
<td></td>
<td>o Gum boots white (men)</td>
</tr>
<tr>
<td></td>
<td>o Boots white (female)</td>
</tr>
<tr>
<td></td>
<td>o Head caps</td>
</tr>
<tr>
<td></td>
<td>o Robust gloves</td>
</tr>
<tr>
<td>Packaging</td>
<td>• Stainless steel table</td>
</tr>
<tr>
<td></td>
<td>• Packaging materials (Jars, bottles, cartons, labels, etc.)</td>
</tr>
<tr>
<td>Laboratory</td>
<td>• Hand refractometer (0-90° Brix)</td>
</tr>
<tr>
<td></td>
<td>• Thermometers (10 – 100 °C)</td>
</tr>
<tr>
<td></td>
<td>• PH – meters</td>
</tr>
<tr>
<td></td>
<td>• Hydrometer</td>
</tr>
<tr>
<td></td>
<td>• Burette for titration</td>
</tr>
<tr>
<td>Additional equipment for fruit concentrate</td>
<td>• Vacuum evaporator</td>
</tr>
<tr>
<td></td>
<td>• Aseptic storage and filling systems</td>
</tr>
<tr>
<td></td>
<td>• Filling and packaging</td>
</tr>
</tbody>
</table>
## Annex 7. Basic equipment for fruits drying

<table>
<thead>
<tr>
<th>Processing stage</th>
<th>Equipment</th>
</tr>
</thead>
</table>
| **Harvesting & Transport** | • Modern harvesting tools  
• Protecting clothing  
• Transporting caretas and wooden crates (Casetas) |
| **Reception/washing** | • Weighing scales (0-50 kg)  
• De-spining device (to remove spines from the fruits)  
• Washing basins (tank) |
| **Peeling and slicing** | • Stainless steel table  
• Stainless steel knives  
• Plastic chopping boards  
• Plastic trays  
• Plastic basins (different sizes) |
| **Drying** | • Hybrid drier (uses solar energy and fossil fuel to heat the drying air) and solar energy and grid power to drive the fan and other electrical appliances. |
| **Packaging** | • Stainless steel table  
• Weighing scale (0-3 kg +/- 1 g)  
• Packaging bags (plastic bags (100 g, 250 g, etc.)  
• Labels |
| **Laboratory** | • Hand refractometer (0-90° Brix )  
• Thermometers (10 – 100 °C)  
• PH – meters  
• Hydrometer  
• Water activity measuring device |
| **Others** | • Workers protective gear  
  o Overalls/Aprons  
  o Gum boots white (men)  
  o Boots white (female)  
  o Head caps  
  o Robust gloves |
| **Additional equipment for the production of animal feed and for oil press** | • |
| **Animal feed from fruit peels and cactus leaves (cladodes)** | • Harvesting tools  
• Caretas for transporting the cladodes  
• Shredder for reducing the sizes of cactus leaves  
• Simple solar dryer for the drying of peels and cladodes  
• Grinder (mill)  
• Packaging bags for storage and marketing |
| **Prickly pear seed oil** | • Oil press  
• Bottle filler  
• Packaging materials (bottles and labels) |