Table 2. General barriers to transfer of adaptation technologies in the agricultural sector and the proposed measures.

General Barriers to transfer of adaptation technology in the agricultural sector	Proposed measures
Absence of economic incentives to encourage farmers to invest in adaptation technology	Market incentives Review Pricing policy of certain inputs Financial support for capital investment through subsidy or credit
Low investment in agricultural R&D resulting in limited human, technical, infrastructural capacity and technology development	R&D supporting policy Seek international and national funding to train technical staff and upgrade infrastructure
Non conducive policy and inadequate institutional framework Weak collaboration between government agencies and research institutions at national level	R&D supporting policy Seek international and national funding to train technical staff and upgrade infrastructure
Farmers resistance to change due to limited know- how and perception that technology is complex	Training and Awareness
Weak linkages between research and extension and end users	Strengthen collaboration between Research and extension
Limited technical support and demonstration projects	Provision of fund to support extension and demonstration Encourage public /private partnership private Training of growers association and service providers (e.g irrigation system assemblers)
Limited market information Poor marketing network and after sale services	Improved access to technology through regional sale points and after sale services
Absence of information and awareness and successful case studies related to climate change adaptation technologies	Training of farmers Awareness campaign on climate change impacts and adaptation strategies Capacity building in Economic analysis Dissemination of economic analysis and successful case studies.
Limited technical capabilities and dissemination scope of the technology	Evaluation of technical capabilities (human , infrastructural and logistics Capacity building of research, extension and farmers

2.2 Action Plan for IPM technology

This section provides a description of IPM technology and the main reasons justifying the selection of this adpatation technology, the overall target for this technology, the main identified barriers hampering its transfer and diffusion, the existing overall enabling environment and the proposed measures/actions to overcome the barriers. It also includes a technology action plan which describes the specific, short, medium and long term actions proposed for the implementation of IPM technology.

2.2.1 About the technology

Integrated Pest Management (IPM) is a broad based approach that integrates a range of practices for economic control of pests. It aims to suppress pest populations below the economic injury level (EIL). It includes controlling insects, plant pathogens and weeds. IPM emphasizes on use of pest control techniques and subsequent integration of appropriate

measures that discourage the development of pest populations, encourage natural pest control mechanisms and keep pesticides to economic levels and reduce or minimize risks to human health and the environment. Chemical pesticides are used only where and when these natural methods fail to keep pests below damaging levels" (Frison et al, 1998; 10).

It comprises of six components namely:1) keeping pest population at acceptable level, monitoring, 2)preventive cultural practices (disease free seed, crop rotation, inter-cropping, pest-resistant varieties, timing of planting and harvest, water, soil and nutrient management, intercropping, mulching, trap crops and field sanitation), 3) pest monitoring, 4) physical control (traps, hand-pulling, hoeing, mowing, and tilling), 5)biological control(use of natural enemies: predators, parasites, and pathogens and sterile male insects, bio-pesticides, plant-based pesticides (biological pesticides)), and 6) responsible chemical control (safer and lower risk pesticides, pheromones and growth regulators) .

Technologies identified to assist local farmers to minimise crop damage and improve crop productivity and resilience to climate change include IPM techniques to control major pest of field and greenhouse crops of economic importance (e.g. mites, melon fly, fruit bats, leafminer and whitefly). A few examples of proven technologies that need to be upscaled includes

1. Demonstration of tree pruning and use of bird net to reduce damage by fruit bats
2. Inoculative releases of predators to control population of Tetranychus urticae a mite causing major damage on solaneceous crops, roses and strawberry.
3. Release of parasitoids(Encarsia formosa and Eretmocerus eremicus) for control of White fly, serious insect pest in greenhouse production
4. Field Sanitation using field cages (augmentorium), protein bait and MAT block to attract and suppress melon fly, Bactrocera cucurbitae, major pest in cucurbits

Over the last 15-20 years, IPM technologies for the control of melon fruit fly (B. cucurbitae), a major pest of cucurbit crops, Plutella xylostella (the diamondback moth DBM), a serious pest of cruciferous crops, have been successfully implemented on a pilot scale with the support of the International Atomic Energy Agency under the Insect Pest Control Sub-programme of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. These projects have helped to develop and strengthen national technical, managerial and scientific skills required for the effective and efficient application of area-wide integrated pest management programmes (AW-IPM) which include a Sterile Insect Technique (SIT) component through fellowship training, scientific visit, technical consultancy and supply of equipment. Thus, expertise to support IPM technologies (use of SIT, rearing of predators/ parasitoids, mass trapping, pheromones sticky traps) exists at Entomology Division of AREU and Agricultural Services. These can be used to support the transfer an d diffusion of new IPM technologies to reduce crop damage, minimise human and environmental hazards and improve farmers' livelihood.

The cost benefit analysis of IPM was estimated to 1.6 (Annex 4 of Report II – Barrier Analysis and Enabling Framework Report), and the Net present Value (NPV) of the benefits derived from it over 10 years was Rs 49.432,000. This clearly justifies public investment in this technology for agricultural development program for food security. Investment in research and development in IPM technologies generally lead to increase in usage of more pest specific, efficacious, less toxic insecticides with lower rate of active ingredient, preventive and suppression strategies and other safer control methods which bring economic benefits to both producers less crop damage and consumers. It also helps to reduce dependence on costly chemicals which can have

adverse environmental and social effects. The technology helps to make savings on pesticides and improves farm profitability as a result of higher crop yield. It also enhances conservation of beneficial organisms such as pollinators and natural enemies. For more details on IPM technology refer to the technology factsheet in Annex of the RI - TNA Report (Mauritius).

2.2.2 Target for technology transfer and diffusion

Barriers to transfer and diffusion of specific IPM technology are closely related to the targets to be achieved and the beneficiaries. The technology is appropriate for present and expected climate scenarios impact on pest damage. This section gives an overall view of targets in terms targeted growers, the percentage crop loss reduction, reduction on reliance of synthetic pesticides, overall improvement in crop productivity and enhancement of farmers' livelihood.

Table 3. IPM technologies and the targeted pest and beneficiaries.

IPM technology	Targeted pest	Targeted beneficiaries
Pruning of fruit trees and use of bird net	fruit bat, a pest of economic importance on litchi, longan and mango	Fruit growers and general public
Inoculative releases of predators to control population of Tetranychus urticae	Mite, a pest of economic importance on solaneceous crops, roses and strawberry	Tomato, chilli, eggplant, rose and strawberry growers
Release of parasitoids (Encarsia formosa and Eretmocerus eremicus)	Whitefly, a pest of economic importance in a range of field and greenhouse crops	Growers of food crops and , ornamentals
Field Sanitation using field cages (augmentorium), protein bait and MAT block	Melon fly, Bactrocera cucurbitae, major pest in cucurbits	Around 70 % of food crop growers

Given that climate change is expected to facilitate the emergence and resurgence of invasive pests and plant disease vectors, current IPM strategies is bound keep pace with rapid and dynamic changes in pest diversity and population. To equipped farmers to cope with increasing levels of biotic and abiotic stress and enable them to continue to grow healthy and high-yielding crops with minimal inputs of agro-chemicals, the target and milestone set for the transfer of this technology is to bring significant changes in their knowledge, attitude and practice. Given the high cost and time required to successfully demonstrate IPM technologies, provide technical support to farmers, train farmers and create public awareness the target for the diffusion of the technology is set over a 10 years period with the aim of attaining 20 % of the land under food crop that is some 1200ha under food crops (involving approximately 2,400 small scale growers).

2.2.3 Barriers and measures to the technology's diffusion

Despite the support and experiences acquired from IPM projects funded by international organisations, the up-scaling and adoption of proven IPM technology have been low at national level. The main reason why it has not gained widespread adoption among local farmers is due to lack of public financing to sustain project-dependent IPM programs. Transfer of this technology is also constrained by the range of expertise and the innovative participatory approach required for its dissemination. The other identified barriers hampering the uptake of the technology are listed below:

1. **Economic and financial barriers:**

- Insufficient financial resources to sustain IPM pilot projects/ program initiated by donor funding and invest in research capacity development and infrastructure to support IPM technology which is resource intensive
- Lack of market incentives to encourage farmers adopt sustainable practices (such as Ecological Food Labelling or Pesticide Environmental Stewardship Programme) and disincentives to discourage the use of chemical pesticides (e.g. tax on chemical pesticides)
- Limited fund to support on-farm IPM demonstration on wide geographical area
- High cost of environment friendly alternatives to chemical pesticides as IPM is time consuming and labour intensive.

2. Non- financial barriers

Market failure and imperfections: Limited access to the technology due to inadequate on farm demonstrations at regional level, restrictive quarantine policy on introduction of predators an parasitoids due to insufficient capacity for pest risk analysis, aggressive promotion of synthetic toxic pesticides by private companies and government, limited availability of quality bio-pesticides and inadequate supplier of IPM technology products.

Policy and regulation: Absence of policy to promote IPM (emphasis still on agricultural intensification) encouraging use of bio-pesticides and low-risk pesticides instead of synthetic pesticides.

Network failures: Limited IPM technology suppliers (mostly government organization), weak collaboration between research, extension and farmers involved in IPM program, aggressive marketing of synthetic pesticides.

Institutional and organizational capacity: Limited human and infrastructure capacity to implement IPM program, weak inter-institutional collaboration, limited coordination between research and extension for IPM project implementation, limited capacity for pesticides residue monitoring and weak planning and assessment of IPM program at institutional level

Human skills: Staff trained in IPM program having to move leading to interruption in the program up-scaling, lack of local expertise in ecosystem evaluation and inadequate extension field officer trained in IPM to act as facilitator in implementation IPM program

Social, cultural and behavioural: Resistance to change from conventional pest control to IPM approach as they are not convinced of their effectiveness, perception of IPM being complex and difficult to implement compared to pesticides which are easy to apply and fast acting, pesticides regarded as an “insurance” against risk of cross loss caused by pests, lack of community efforts (non-adoption by neighbouring fields) and less concern about long term negative impacts of pesticides

Information and awareness: Poor communication between researchers and farmers, limited training of research, extension and farmers lack awareness on IPM techniques, lack of technical IPM information resources and package of IPM compatible practices (cost and effectiveness), lack of information on value of environmental damage due to chemical pest control, iinadequate consumer awareness of benefit of IPM to environment, and health and ineffective dissemination of IPM technology(top to bottom approach or one – way system based on teacher- learner model

Technical: Limited capacity (human and infrastructure) to support National IPM program, limited national expertise in IPM - multidisciplinary team to support IPM to farmers (field monitoring, pest scouting, pest surveillance and data collection), limited logistic support to undertake field demonstration (site, materials, maintenance, transport,), Crop and pest specificity of IPM package , effectiveness of IPM technology only if undertaken a wide-area level

Others: Limited information on weather forecast, and insufficient logistic facilities to encourage environmentally sound pest control (e.g no facility for disposal of pesticides and empty containers), given increasing pest outbreak and pressure as a result of changing climate, there is need review policies and undertake measures to provide farmers an understanding of the agro-ecosystem ecological concept , IPM practical application so as to assist them in reducing the risk of crop failure and thus improve their livelihood and national food security. .

Despite the above identified barriers hindering the transfer of IPM technologies, several national policy documents and the government vision to develop a cleaner and safer environment provides the appropriate enabling environment in favour of promoting IPM. The National Environment Policy which aims at reconciling environmental sustainability with economic and social development to provide a better quality of life to Mauritian population is one of the key conducive framework. It encourages adoption of Good Agricultural Practices (GAP) for long term sustainability of agricultural production system. National agricultural policy documents such **Strategic Options in Crop Diversification and Livestock Sector 2007-2015** and the **National Biodiversity Action Plan (2006-2015)** also directly or indirectly support integrated approach to pest management for the preservation and enhancement of the natural environment. Moreover, the government's strong commitment to promote sustainable development, the "Maurice Ile Durable" Policy, Strategy and action plan 2012 aims at promoting sustainable agriculture through minimising use of agrochemicals and pesticides so as to prevent deterioration of groundwater and lagoon water quality and protect health of farm workers and consumers. Other existing enabling environment to the transfer of IPM technologies includes the existing infrastructure and technical expertise in IPM, interest of ono-governmental agencies as well as pesticide companies to engage in IPM, existence of farmers' associations to take decision collectively, relatively high level of literacy among local farmers and farmers knowledge and involvement in decision making. These conditions are conducive to enable IPM control actions to be taken collectively thus ensuring greater success at an area-wide management.

In light of the key barriers and existing enabling environment, the main measures identified to overcome the barriers and promote IPM technologies are sustained investment in research and development in IPM techniques, building infrastructure and technical capacity, including human resources development to support IPM project implementation, economic evaluation of IPM techniques, establishment of market incentives such as IPM brand, enforcement of of relevant policies, financial disincentives to discourage use of synthetic pesticides, encourage farmers participation through Farmers field schools, strengthening institutional collaboration, encourage regional cooperation and awareness raising.

2.2.4 Proposed action plans for IPM technology

Following identification and detailed analysis of the barriers to the transfer and diffusion of IPM technologies, this section will focus on the proposed measures essential to create the enabling environment conducive to encourage widespread adoption and dissemination of this technology among local farmers. The technology action plan for promoting IPM technologies include the

- economic and financial measures (incentives and disincentives)
- policy and regulation tools
- market incentives
- research and development capacity
- information and awareness raising (demonstration projects); and
- support to farmers.

Table 4. Technology action plan for IPM technology.

Barrier Category	Barriers	Justification for action	Proposed measures /actions	Time Frame (yrs)	Estimated cost (Rs)	Implementing agencies	Funding sources	Indicators of success (IOS) & Risk
Economic and financial	Insufficient financial resources to sustain IPM pilot projects & investment in research capacity development and infrastructure	Need to sustain fund to promote and upscale IPM program to help to minimise crop losses and ensure food security	Information on economic impact of damage due to pest and diseases convey to policy makers for action and prioritisation of adaptation in agricultural sector Government to Increase R&D budget for up-scaling IPM Programs	0 - 5	15.0 M	government agency, private sector	Government & International organisation	IOS- IPM program sustained and demonstration undertaken Risk – IPM is not attractive to investors /donor
			Financial incentives to assist farmers shifting from conventional to ecological farming practices incentive	5 - 10	5.0 M			
			Economic feasibility study of IPM program	10- 20	1.5 M			
Policy and regulation	Absence of supportive policy to promote IPM and discourage promotion of chemical pesticides	Need to minimise use of chemical pesticides for sustainable agriculture / In line with food safety and MID policy	Develop an IPM strategy and policy across sectors to foster IPM adoption and ensure sustainable development in line with MID policy and strategy Disincentives to discourage use of synthetic pesticides	0 - 5	0.8 M	State law Office, MAIFS, MOESD	Government funding	IOS- Policy put in place and enforced Risk – Lack of political will
			Review of quarantine policy and regulation to facilitate introduction of IPM technology (biopesticides/ predators, parasitoids)	5 - 10	0.4 M			
			Regulating sale of pesticides and disposal of empty pesticide residuEnforce food safety regulation w.r.t. pesticide residue monitoring	10- 20				
Market failures and Imperfections	Lack of market incentives such as Ecological food Labelling	Provision of market / financial incentives to encourage farmers to shift to sustainable practices	Public awareness on alternative to chemical pesticides	0 - 5	1.5 M	Govt of Mauritius, Private sectors, Mauritius Standard Bureau and Certification bodies	Government and private sector and NGOs	IOS- setting of Standard for Ecological food label , No. of farmers trained and certified Risk- Low demand for IPM products
			Encourage setting up of private standard for Ecological food labelling (voluntary) Setting of certification scheme Introduce subsidy on inputs used in IPM Public awareness of Ecological food label/ low risk food	5 -10	3.5 M			
R&D capacity	Limited capacity for Research and development on IPM / Lack of skilled human resources Limited pesticide residue monitoring facility	Build sustainable R &D capacity in IPM In line with food safety and to improve market access	Develop IPM training program for researcher, extension, farmers and market actors Strengthen institutional capacity (human and infrastructural) Upgrade Infrastructure to support IPM program Setting of Farmers Field School in IPM Development of locally adapted IPM technology specific to crop & pests under local conditions	0 - 5	0.8 M	MIAFS, AREU, UoM, , International Research centres	Government and International funding	IOS-No of researcher, extension and farmers trained, No. of IPM compatible technologeis tested and disseminated IPM integrated in School curriculum Risk- Trained staff moving out of IPM program

			IPM principles to be include in school curriculum	5 – 10	0.5 M			
			Continuous investment in institutional capacity (human resource development and infrastructural and logistic support)	5- 20	20.0M			
	Limited pesticide residue monitoring facility	In line with food safety and to improve market access	Inventory of pesticide commonly used and capacity for determination of pesticide residue Enforce capacity of pesticide residue analysis at food Lab (human and infrastructure)	0-5	4.0 M	MAIFS- Food Lab Ministry of Health AREU Extension	Gov of Mauritius	IOS-No of pesticide residue analysis Risk- Poor linkage between Research , extension and market actors Risk –there is no enforcement / sanction
Institutional and organizational capacity	Lack of cooperation and communication between the involved institutions leading to failure of IPM projects	Need to foster collaboration between all stakeholders involved in agriculture	Strengthen collaboration between institutions (Govt. Research institute, academia , private sectors, extension and farmers) and cooperation at regional level and promote data and information sharing	0-5	0.25 M	MAIFS, Govt of Mauritius , COI, farmers associations	Regional and national	IOS- No. of exchange meetings/ workshop
Social and behavioural	Resistance to change from chemical control to IPM	To demonstrate overall benefits of IPM practices	Encourage Farmers / community participation in IPM	0-5	1.0 M	MAIFS, AREU, SPWF, NGOs,	National	IOS- No. of farmers implement ing IPM Risk – cheaper pestcides
Information and awareness	Inadequate public awareness of IPM and training of farmers	Need to inform public for decision making	Public awareness of potential impacts of pesticide on env. and health and alternatives sound pest and disease control	0-5	0.4 M	MAIFS, AREU . SPWF, NGOs, Farmers associations , Mins of Health &QL, Media	National	IOS- No. of TV spots, Radio talk Risk – Lack of fund
			Economic analysis of IPM program	5 -10	0.35M			
			Continuous training of farmers	5 - 20	1.2 M			

2.3 Action Plan for Micro Irrigation

2.3.1 About the technology

Micro-irrigation is of 2 types: the low-cost micro irrigation such as low-head, low-cost gravity-fed drip (GFD) irrigation kits, micro sprinklers, micro-tube drip system suited for smallholder farmers and highly sophisticated, capital intensive pressurised commercial drip irrigation. It is commonly used for irrigation of high value horticultural crops such as high value vegetables, fruits and ornamentals in open field, greenhouses or orchards. It delivers water precisely and efficiently and is thus useful in addressing the growing competition for scarce water resources and has shown to have positive effects on yield, incomes, and food security. It reduces labour requirement, weed problem and can also be used for fertigation, which is the application of fertiliser through irrigation system. It is applicable to operate with large or small water capacities and over a range of field sizes, topographic and soil conditions and is well suited for automation. This technology requires:

- a water source which can be from small streams, boreholes, tank, reservoir, field pond and rainwater harvesting;
- a water storage facility;
- design/ layout of irrigation system;
- installation of irrigation system which consist of pipes, valves, filters and small drippers or emitters for drip irrigation and a network of pipes with spray heads;
- a pump to lift or pressurised pump to convey and apply irrigation efficiently (except, in case of a