Technical University of Denmark

Evaluating and prioritizing technologies for adaptation to climate change. A hands on guidance to multi criteria analysis (MCA) and the identification and assessment of related criteria

Trærup, Sara Lærke Meltofte; Bakkegaard, Riyong Kim

Publication date:
2015

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):
Trærup, S. L. M., & Bakkegaard, R. K. (2015). Evaluating and prioritizing technologies for adaptation to climate change. A hands on guidance to multi criteria analysis (MCA) and the identification and assessment of related criteria. Copenhagen: UNEP DTU Partnership.

Evaluating and prioritizing
technologies for adaptation
to climate change

- *A hands on guidance to multi criteria analysis (MCA) and the identification and assessment of related criteria*

UNEP DTU Partnership

Sara Trærup and Riyong Kim Bakkegaard

Climate Resilient Development programme

May 2015

Contents

Chapter 1. Introduction

Identifying, assessing and evaluating technologies for climate change adaptation is a complex, dynamic process that cuts across scales, sectors, and levels of intervention. Adaptation itself is characterized by many uncertainties, and it extends long past usual project cycles.

Technology development and transfer is an area of increasing priority on the international agenda on adaptation to climate change. Methodological and operational aspects of technologies in the area of adaptation to climate change are relatively underdeveloped with a number of prevailing challenges, including (a) defining and operationalizing the concept of technologies for adaptation much clearer; (b) developing the methodologies for how to assess and prioritize technologies for adaptation further and (c) ensuring that the relevant available information and knowledge is fully utilized and integrated in the processes.

In the transfer of adaptation technologies it is imperative to ensure that they address the underlying stressors to vulnerability to climate change stressors (like access to basic resources such as water, infrastructure and public facilities) and that they are suited to local conditions. If one ignores such issues, the technologies may be ineffective, and may prove maladaptive if implemented without recognition of relevant social contexts and environmental processes. Therefore it is vital to identify and assess technologies against appropriate criteria when prioritizing technologies.

The objective of this guidance is to guide consultants, decision makers and technical experts on how to facilitate discussions for prioritizing adaptation technologies, and to support the stakeholders in identifying appropriate criteria for this analysis.

The guidance has been complemented by an Excel spreadsheet that provides a template for following this guidance. The Excel sheet can be used to rank the technologies and to carry out a sensitivity analysis.

What is adaptation technology?

The Intergovernmental Panel on Climate Change (IPCC) (2000), in its special report on Methodological and Technological Issues in Technology Transfer, defines technology as 'a piece of equipment, technique, practical knowledge or skills for performing a particular activity.' The *UNDP Handbook for Conducting Technology Needs Assessment for Climate Change* (United Nations Development Programme (UNDP) 2010), defines the concept of technologies for adaptation very generically as: 'All technologies that can be applied in the process of adapting to climatic variability and climate change' (UNDP 2010). A UNFCCC report on the development and transfer of technologies for adaptation to climate change proposes the following definition: 'the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change' (UNFCCC 2010).

Chapter 2. Multi Criteria Analysis for prioritizing adaptation Technologies

This chapter provides a basic step by step guidance for conducting multi criteria analysis (MCA) for the prioritization of technologies for climate change adaptation.

MCA facilitates the participation of stakeholders and hence allows normative judgments, while incorporating technical expertise in the adaptation technology assessment. Based on the assessment, adaptation technologies are prioritized to indicate which technologies should be implemented first. MCA is useful when comparing multiple options across a multiple set of criteria. A prioritization exercise could be done comparing multiple technologies to solve this problem, including desalination, water reclamation and reuse rainwater harvesting from roof tops. MCA can also be used to prioritize technologies applied to solve different problems, which ideally should work towards the same objective.

When assessing adaptation technologies using MCA, it usually involves combinations of some criteria which are quantified in monetary terms, and others for which monetary valuations do not exist. It also allows for a mix of quantitative and qualitative criteria, with the result that the quality, form and format of information may even differ within the same assessment of technologies. Wherever it is possible to quantify costs and benefits in monetary terms, then this data should be included in the MCA.

Multi criteria analysis (MCA) provides a structured framework for comparing a number of adaptation technologies across multiple criteria. A major benefit of using MCA for prioritizing adaptation technologies is the ability to include the preferences of stakeholders involved in the process, emphasizing the importance of having appropriate representation of stakeholders during the prioritization process.

The steps for undertaking the MCA follows the approach as summarized in Dodgson et al. (2009):

1. Establish the decision context. What are the aims of the MCA, and who are the decision makers and other key players?
2. Identify the options
3. Identify the criteria
4. Describe the expected performance of each option against the criteria.
5. 'Weighting'. Assign weights for each of the criteria to reflect their relative importance to the decision
6. Combine the weights and scores for each of the options to derive and overall value.
7. Examine the results
8. Conduct a sensitivity analysis of the results to any changes in scores or weights

An important feature of MCA is its ability to use the expert judgment of the stakeholders e.g., within a sectoral working group in TNA. This includes establishing targets and criteria, estimating relative importance weights and in judging the contribution of each technology to each performance criterion. The sectoral working group is expected to arrive at a collective decision. Stages 3, 4 and 5 should be carried out in a workshop setting where the adaptation technologies are assessed by sector working groups with a facilitator to lead the discussion. The facilitator can also ask one of the experts to lead the discussions; however, the facilitator needs to be present to ensure that the process follows the MCA structure. It is important that all working group members have been provided, and are familiar with, technology fact sheets for all the technology options (long list) before the meeting (minimum one week before). It is the responsibility of the MCA facilitator to prepare and circulate these fact sheets (Annex A).

During the prioritization process, the MCA methodology is used to structure the prioritization process.

Throughout this chapter, an example of each step in the prioritization process is given in case boxes based on the experiences from conducting a Technology Needs Assessment in Mauritius.

Step 1: establish decision context

As a first step in the process of prioritizing technologies, the context in which the decision takes place should be considered. In the particular setting of technology needs assessments, it is relevant to consider, for example, existing national and local priorities, plans, and ongoing projects in the context where the technologies are going to be transferred and diffused. Also, an overview should be made of the existing technologies in the specific sector in order to identify potential gaps.

Along with identifying the context in which the decision is made, the broader objectives of the analysis should be spelled out. This could for example be to reduce crop vulnerability to prolonged periods with drought. One way to come about this is to evaluate what the broader objectives of the technologies are. In many cases the major focus will be to meet specific development objectives, and the technologies should be assessed in relation to how they influence key development policy goals in the national/local context. An example of a broader objective for the water sector could be *establishment and maintenance of a stable water supply to specified districts with 90 percent of the district population having stable access to water sources by 2020*. With this broader objective, the necessary technologies to meet this objective can be identified.

In summary, the first step can be summarized as follows:

1. Decide structure of the MCA, required stakeholders/engagement
2. Describe context
3. Identify the broader objectives of the analysis

Context and objectives of MCA of adaptation technologies in the agriculture sector in Mauritius
The *Blueprint for a Sustainable Diversified Agri-food Strategy for Mauritius*, 2008-15, addresses food security through improving self-sufficiency status of a number of strategic crops in the short to medium term. It aims at reducing the gap between local food production and consumption and the dependency on imported food through investment in the following priority areas such as modern production techniques,

sustainable land management and water conservation, quality improvement, integrated pest management, irrigation facilities and meat and milk production.

A *Food Security Fund* (policy instrument) has been set up to increase the resilience of Mauritius towards food self-sufficiency and to face subsequent global food and feed crisis by increasing production of foodstuff locally and at the regional level by partnering with neighboring countries. The strategy and policy instrument were not designed to address the climate change-agriculture nexus directly. Nevertheless, they cover several 'no regrets'[1] measures such as regional diversification of food production that will reduce vulnerability to the adverse effects of climate change, and hence increase climate resilience of this sector. Further, the Fund also provides for promoting local seed production to improve seed security, fodder production, livestock genetic improvement, research and development to develop improved crop varieties, training in agro-processing value addition, meat and milk production and other adaptation measures such as the *Food Crop Insurance Scheme, Post harvest treatment and storage facilities* and *Sheltered Farming.* The Fund also makes provision to modernize irrigation schemes for small planters.

Broader objectives

Being aware of the impact of climate change, variability and climate extremes, adaptation technologies should assist farmers in Mauritius to cope with the challenge of climate change (and climate variability) and increase the resilience of the sector.

Overview of existing technologies in the agricultural sector

Being aware of the impact of climate change, variability and climate extremes, a number of adaptation technologies have already been identified and proposed to assist farmers to cope with the challenge of climate change (and climate variability) and increase the resilience of the sector. These are summarized in Table 9. The options have been implemented to varying degrees and levels of success, but their systematic application has been lacking.

Adaptation measures proposed for agriculture in national documents.

National documents	Proposed adaptation options
First Technology Need Assessment Report (2004)	- Increasing water use efficiency through more performing irrigation systems; - Trash blanketing / green cane harvesting (sugar cane) - Changing harvest period; - Land use change (shifting areas); - Crop change - Adopting drought tolerant cultivars - Introduction of more performing cultivars - Integrated Pest management - Rational use of fertilizers and herbicides
Second National Communication (2010)	- Introduction of new varieties or cultivars; - Shifting crop production zone. - Increasing irrigation water requirement - Sustainable land/ soil management of land/soil - Promoting conservation and sustainable agricultural practices; - Combating land degradation; - Biotechnologies to improve water-use efficiency of crops or plant more resistant crop varieties; - Provide farmers with Insurance and security for their investments; - Application of new and sustainable technologies, e.g. protected cultivation; and - Establishment of an early warning system for pest and disease management.

[1] Defined as adaptation options (or measures) that would be justified under all plausible future scenarios, including the absence of manmade climate change.

Step 2: Identify technologies

The identification of technologies for adaptation to climate change can be informed by other processes, e.g. national and local climate change vulnerability and risk assessments. The consultants can do a review of such studies. Another source of information on technologies is the TNA Guidebooks for adaptation. In addition, the technologies should be identified based on the expert views, and brainstorming with relevant stakeholders, during sector working group sessions. The technology identification process may result in a long list of technologies, and the identified technologies could be regrouped under different categories. Lastly, the list of technologies should be refined based on the MCA facilitator's discussions with the working group experts to include only 6-15 technology options for each sector.

Based on the 6-15 identified technologies, the consultant/MCA facilitator should prepare technology fact sheets. Annex A gives a template for the fact sheets which can be used in the preparation. The content of each technology fact sheet should include: brief technology description, the costs of the technology, the application potential in the country, and other social, economic, and environmental benefits, etc.

Identifying a long list of technologies

Based on the current challenges faced by the agricultural sector with climate events over the past decade and the vulnerability of the sector to predicted climate change, a longlist of 25 possible adaptations technologies were identified to improve the resilience of the agro-ecosystems and the livelihood of farmers. The technologies were identified through expert views and brainstorming with relevant stakeholders during the sector working group session at the national Inception Workshop. Thorough discussions, it was decided to focus on technologies of benefits to small-scale vulnerable foodcrop growers, livestock breeders and to local biodiversity and forest resources.

The technology identification exercise for the long list of technologies drew from multiple sources and the national context, including (1) adaptation technologies proposed in previous national documents;(2) technologies currently in practice and supported by national agricultural policy; (3) initiatives in the pipeline (e.g. sheltered farming and rainwater harvesting);(4) appropriateness of technologies in the local context (e.g. fog harvesting, grain storage); and (5)social acceptability (e.g. restricted use of genetically modified organisms), among others.

The adaptation technologies identified were then regrouped under different categories (or typologies): sustainable water use and management, planning for climate change variability, soil management, sustainable crop management, sustainable livestock management, sustainable farming system, land use management, and capacity building and stakeholders. The classification of adaptation technologies and their status are summarized in the table below.

Category	S.N	Adaptation Technologies	Status of the technology in Mauritius
Water Use and management	1	Improve water conveyance system	Implemented by the Irrigation Authority
	2	Micro irrigation (drip and sprinkler)	Its adoption by small scale farmers is low due to high initial investment.
	3	Rainwater harvesting and improved field ponds for water storage	A scheme has recently been launched to assist farmers in investing in rain water harvesting infrastructures.
	4	Use of treated wastewater for irrigation	Presently it can be used for irrigation of sugar cane but regulation need to be put in place.
Planning for climate change variability	5	Improve agro-meteorological information network for forecasting and Early warning - data collection, processing and dissemination	Presently not being implemented.
	6	Reinforcing pest and disease monitoring and early warning system	It is limited to diseases of major crops but available to a small group of farmers through SMS

Soil management	7	Integrated nutrient management (organic, inorganic, bio-fertiliser, compost)	Technology implementation is very low and need to be reinforced.
	8	Composting of agricultural waste at household and farm level	Need to be encouraged at all levels and the use of compost should be further promoted.
Sustainable crop management,	9	Reinforce conservation of locally adapted varieties and seed production of locally adapted crop varieties	Need to be reinforced
	10	Enhance R&D in breeding, of varieties/breeds better adapted to drought, heat, disease (crop with better shelf life and nutritional value)	Limited to only a few crops due to limited resources
	11	Low-water consuming crop species and varieties	Not yet implemented
	12	Integrated Pest and Disease Management (use of physical control measure and bio-control agents/ bio-pesticide and crop management	Presently being implemented in few location but need to be further reinforced.
	13	Protected cultivation (integrating rainwater harvesting and reuse of leachate)	Protected cultivation is being implemented but not integrated with rainwater harvesting and reuse of leachate
	14	Reduce postharvest losses- training and postharvest facilities	New technology need to be promoted to reduce food losses
	15	Increase foodcrop and feed production – promote soilless culture and rooftop gardening	Actually being implemented and being supported by Food security Fund.
Sustainable livestock management	16	Livestock disease management / training	Presently being implemented
	17	Livestock insurance scheme	Not yet implemented
	18	Biotechnologies – conservation of local adapted livestock breed for use in breeding via controlled mating	Need for reinforcing conservation of local breeds
Sustainable farming system	19	Mixed farming	Practised on a limited scale
	20	Tree planting and tree management / pruning	New technology need to reinforced
Land use management	21	Watershed management and agroforestry	New technology, not yet implemented
	22	Wetland restoration and afforestation	Need to be further reinforced.
	23	Monitor land use change / land bank – incentive for sustainable land management	Not yet implemented
	24	Mapping of Vulnerable areas (drought , floods)	Mapping of flood prone areas in the pipeline.
Capacity building and stakeholders organisation	25	Capacity building of research and extension to identify and adapt green and environment friendly technologies / indigenous technologies for dissemination to farmers/ schools	Implemented but need to be reinforced.

To arrive at a shortlist of technology options for adaptation in the agriculture sector a pre-screening process was carried out.

The pre-screening of the technologies was carried out during a sector working group meeting led by the sector consultant and involved discussions with the experts on the technical feasibility and adaptation benefits of each of the 25 identified potential adaptation technologies. The discussion of technologies were based on the likely future scenarios of climate impacts on Mauritian agriculture, expert knowledge and pre-screening criteria as prescribed in TNA Handbook, namely: (i) technical potential of the technology; (ii) contribution to improve climate resilience; (iii) cost of the technology and (iv) coherence of the technology with national development strategy and policies.

As a result of the working group discussions, a list of nine technologies were retained for the MCA.

1. Micro irrigation (gravity fed drip & mini and micro sprinkler irrigation)
2. Reforestation of the water catchment area of the main Reservoirs of Mauritius
3. Index based weather disaster subsidized agricultural insurance scheme for food crop
4. Low cost postharvest technology (crates and evaporative cooling chambers)
5. Decentralised rapid pest and disease diagnosis service (plant clinic)
6. Reinforce breeding and conservation programme for crop adapted to change in climate
7. Education and awareness raising among farming community to promote adaptation to climate change

8. Improving Agro-meteorology Information network for forecasting and Early Warning System
9. Up-scaling of locally proven IPM technologies for control of pest of economic importance

Subsequently, the sector consultant developed technology factsheet (TFS) for each of the nine listed technologies. The TFS contain relevant information on the technical aspects of the technology implementation, including its installation, operation and maintenance, efficiency, cost, and the benefits / opportunities, as well as the barriers for each short-listed adaptation technology. Bilateral meetings were also held with key stakeholders to collect information for the TFS on the market potential and status of the technologies in Mauritius, and to acquire technical information to estimate the incremental cost of the adaptation technologies.

The technology fact sheets were validated after members of the working group had been given ample opportunities to provide their comments and suggestions. Bilateral meetings were also held with key institutions before finalizing the technology needs.

Step 3. Identify criteria

The identification of criteria against which technologies will be ranked should be based on a clear and transparent process. The technical working group members involved in the MCA process must understand the meaning of the criteria and how criteria are framed as well as the implied trade-offs. Criteria should show a variation across technologies. There is no use in selecting criteria, which do not change across the different technologies.

The criteria can be derived from the objectives and goals specified in Step 1.

If the criteria measures are qualitative and therefore cannot be measured in numbers, they should be converted to a numerical form on a scale, e.g. from 0 to 100 where "0" means the least preferred option and "100" means the most preferred option. There are broadly two sets of criteria, one related to the benefits and the other related to costs. It is important to ensure that the selected criteria:

- include all relevant aspects
- are not redundant, meaning that one criterion is not repeating what is already assessed through another criterion and therefore unnecessary
- are well-defined
- mutually independent, meaning two criteria are independent if they convey no information about each other and, as a consequence, information about one of the two does not change the assessment of the other. For example cost effectiveness and cost of implementation are related to each other.
- are not evaluating/judging the same issue
- take into account impacts over time

For the prioritization of technologies, it is recommended to select 7-10 criteria. Then build a decision matrix, either using a table or, preferably, a spreadsheet. Place the criteria in the top row. The technology options can be added into the first column.

Table 1. Illustration of decision matrix for MCA.

	Criterion A	Criterion B	Criterion C	Criterion ….	Criterion n	Total scores
Technology 1						
Technology 2						
Technology 3						
Technology 4						
Technology ..						
Technology ..						
Technology n						

Criteria selection

In Mauritius, a set of locally-validated criteria was selected in order to prioritize the adaptation technologies. Before the sector working group meeting to prioritize technologies, the consultant had prepared some criteria and collected expert views on the ease of assessment and availability of each of the measurable criteria.

Only criteria that are independent of each other (or mutually exclusive) were retained. Economic criterion such as job creation was found to be difficult to calculate.

Criteria for MCA for prioritization of adaptation technologies in agriculture sector.

Criteria category	Criteria	Scoring Scale
Institutional/ implementation barrier	Ease of implementation	0 : Very difficult → 100: Very easy
	Use and maintenance /replicability	0 : Very difficult → 100: Very easy
Public financing needs	Cost to set up and operate the technology (resources, skills, infrastructure..)	Additional cost of per beneficiary /year (Rs)
Economic	Catalyzing private investment	0:- Very low → 100: Very high
	Improving farmer income and ability to reinvest	0:- Very low → 100: Very high
Environmental	Contribution of the technology to protect and sustain ecosystem services	0:- Very low → 100: Very high
Climate-related	Enhancing resilience against climate change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	0 : Very difficult → 100: Very easy
Social	Contribution to social and sustainable development (benefit to society)	0:- Very low → 100: Very high
Political	Coherence with national development policies and priority	0:- Very low → 100: Very high

One of the crucial tasks of the consultant during the finalisation of the MCA criteria was to ensure that all working group members had the same understanding of the meanings of the criteria. This was an important step to be accomplished before scoring the retained technologies against the MCA criteria.

Step 4. Ranking of technologies

In this step, the outcome and performance of each technology are evaluated against each of the criteria. The MCA facilitator is expected to build consensus around a particular score for each technology on the respective criterion. Disagreement has to be recorded and later analysed by carrying out sensitivity analysis with different scores (see Step 8). The scoring scale could be from 0 to 100, using 0 as the least preferred technology and 100 as the most preferred technology and each technology is evaluated against each criteria.

Table 2

Score	General description
0	Used when information on a technology does not apply to the particular criteria
1-20	Extremely weak performance; strongly unfavourable.
21-40	Poor performance, major improvement needed.
41-60	At an acceptable or above level
61-80	Very favourable performance, but still needing improvement
81-100	Clearly outstanding performance which is way above the norm.

To reach a score for each of the criteria and technologies, it is recommended to have the group discuss and vote on one criterion at a time. Basically, the expert group should discuss the importance of the criterion and then reach a consensus on the score for each technology against this criterion. Alternatively individual expert scoring can be made and submitted on a scoring sheet to the MCA facilitator who can then calculate the average score.

It is essential to make sure that the weighted scores (see step 5) can be added, in other words, all criteria should be formulated in positive terms.

It is also important to note that whenever some costs and benefits ***can*** be valued in monetary terms, either by direct observation of prices if appropriate or indirectly using generally accepted economic valuation techniques (such as cost benefit analysis, cost effectiveness analysis, etc.), then these data should naturally be used within the MCA scoring process (Dodgson et al. 2009). For example it could be possible to collect information on a criterion on the cost of implementation of the technologies. These cost estimates should then be converted into the relative scoring scale in order to compare them with the scoring for other criteria. An example is given in Table 3 below.

Table 3. Converting absolute numbers to relative scores when a lower value preferable

Technology	**Criterion category:** Public financing needs. **Specific criterion:** Cost to set up and operate the technology (rupees per beneficiary/year)	Relative scoring calculation $=100*(x_{max} - x)/ (x_{max} - x_{min})$	Result, relative scoring scale
Micro irrigation (drip & sprinkler)	7585	100*(7585-7585)/(7585-113)	0
Index based weather disaster insurance	4660	100*(7585-4660)/(7585-113)	39
Agrometeorology for forecasting and Early Warning System	297	100*(7585-297)/(7585-113)	98
Decentralised pest & disease diagnosis	234	100*(7585-234)/(7585-113)	98

Upscaling of locally proven IPM techno.	2441	100*(7585-2441)/(7585-113)	69
Conservation and Breeding	1082	100*(7585-1082)/(7585-113)	87
Low cost postharvest technology	2703	100*(7585-2703)/(7585-113)	65
Education and awareness raising	847	100*(7585-847)/(7585-113)	90
Reforestation catchment area	113	100*(7585-113)/(7585-113)	100

In the example given in Table 3 it is good to have a low score, since a low score is related to a low cost. However, in some cases highest preference should be given to a high score, or in other words a high score would be positive. This could be in a case where the criteria reflects the amount of water saved and hence a high score is equal to a large quantity of water is saved, which is preferable. For such a case, the relative scoring can be calculated as shown below in Table 4.

Table 4. Converting absolute numbers into relative scores when a higher value is preferable

Technology	**Criterion category:** Contribution of the technology to protect and sustain ecosystem services **Criterion x:** saved piped water (m^3) per beneficiary over the life span of the technology	Relative scoring calculation $=100*(x - x_{min})/ (x_{max} - x_{min})$	Result, relative scoring scale
Sensitisation Programme	80	100*(80-40)/(120-40)	50
Reuse Treated wastewater	60	100*(60-40)/(120-40)	25
Desalination	40	100*(40-40)/(120-40)	0
Stormwater Harvesting	70	100*(70-40)/(120-40)	37.5
Rainwater Harvesting	120	100*(120-40)/(120-40)	100
Water Fixtures & Fittings	80	100*(80-40)/(120-40)	50

Some general recommendations for evaluating technology against each other, and which are not criteria specific, also include:

- technologies should be evaluated based on the same climate change scenario
- technologies could be evaluated at a project or scheme level to accommodate varying levels of cross-national resources
- assessments should be made across the same time frame for all technologies considered.

Technology Fact Sheets for MCA
In Mauritius, the technology fact sheets were circulated to all members of the sector working group for familiarization with the technology options prior to the MCA prioritization exercise, which involved scoring, weighting, and sensitivity analysis.

Scoring: A performance score card in which each row describes a technology option and each column describes the performance score of the options against each criterion was developed and filled following thoroughly discussion with the technical working group during two MCA working group sessions. The assumptions made and methodology used to work out the public financing needs (cost to set up and operate the technology) was discussed and agreed was cost per beneficiary per year. The cost was then standardized between 1(most costly) and 5 (least costly). For the other criteria, technology options were scored on a scale anchored at 1 (lowest score) and 5 (highest score) based on the expected merits of the technology.

Step 5. Assign weights to each of the criteria

When all technology options have been scored against all criteria, the scores still can't be compared because preference of one criterion does not necessarily equal the preference on another criterion. Therefore, each criterion needs to be assigned a weight to reflect the weight of importance that stakeholders assign to each of the specific criterion. When the criteria have been weighted, the scores against all criteria can be compared.

Weighting can be done as follows: First, arrange the final list of criteria in declining order of relative importance. Then assign a weight between 1 and 100 to each criterion, making sure that the sum of all weights totals 100.

Table 5. The MCA facilitator is expected to create consensus among the experts on a score for each criterion a percentage score between 0 and 100. The scores must add up to 100.

Criterion	Weight (%)
1	25
2	10
3	20
4	5
5	5
6	35
Total	**100**

The decision matrix shown in Step 3 can now be expanded to include the weighted scores. In the bottom line, the weight for each criterion is added, and the weighted score is calculated for each scoring point. For example if Technology 1 has a score of 45 and the weight for Criterion A is 10, then the weighted score of Technology 1 for Criterion A is 45*10% = 4.5.

It is possible to assign zero weight to the criteria and henceforth treat all criteria equally.

Table 6

	Criterion A	Criterion B	Criterion C	Criterion ….	Criterion n	Total weighted

	scores
Technology 1	
Technology 2	
Technology 3	
Technology 4	
Technology ..	
Technology ..	
Technology n	
Criterion weight	

Assigning weights

For the TNA project in Mauritius, expert judgements were sought from members of the agriculture sector working group to assign a weight to each criteria to reflect their relative importance in the decision making process. The cumulative sum of weights across all criteria was equal to 100.

Step 6. Combine weights and scores

In this step, all the weights and scores for each of the options are combined to derive an overall value.

The total weighted score of each technology option are calculated for each technology by multiplying its relative score (see step 5) for each criterion by the corresponding weight given to that criterion.

Table 7. Combining weights and scores. An example inspired by the TNA project in Lebanon for agriculture sector (MoE 2012)

		Conservation Agriculture	
Criteria	Weight	Score	Weighted score
The budget (capital and operational cost)	23	80	18
Economic impact of the technology	20	80	16
Improving resilience to climate change	18	35	6
Effectiveness and suitability of technology	15	45	7
Social suitability (readiness)	10	75	8
Human and information requirement (readiness)	15	40	6
Total	100	355	60

Step 7. Examine results

The process undertaken in step 6 will result in a list of ranked technologies prioritized according to their scoring against the criteria and weights given to each criterion, as identified by stakeholders and MCA facilitator.

The technology scoring the highest total relative weighted score can be ranked as the most preferred technology, whereas the one with the lowest relative score are ranked as the least preferred option. The ranked list of technologies combines all criteria on the same relative scale, and presents the overall preference for technologies.

Prioritized list of technologies and the final refinement

The results of the MCA exercise were carefully examined by members of the sector working group to see if the ranks were logical. Firstly, it was ensured that the scores given to different criteria were consistent and reflective of the technological merits. The scope of the technology options was discussed again and a proven IPM technology, fruit bat control, was subsequently included for up-scaling due to the extensive damage they cause.

Ranking order of priority Adaptation technologies for the agriculture sector

1. Reforestation of the water catchment area of the main Reservoirs of Mauritius
2. Up-scaling of locally proven IPM technologies for control of pest of economic importance
3. Micro irrigation (gravity fed drip & mini and micro sprinkler irrigation)
4. Decentralised rapid pest and disease diagnosis service (plant clinic)
5. Reinforce breeding and conservation programme for crop adapted to change in climate
6. Education and awareness raising among farming community to promote adaptation to climate change
7. Low cost postharvest technology (crates and evaporative cooling chambers)
8. Improving Agro-meteorology Information network for forecasting and Early Warning System
9. Index based weather disaster subsidized agricultural insurance scheme for food crop

Though reforestation of the water catchment area of the main reservoirs of Mauritius was identified as the highest priority, it was not considered among the first three prioritised technology options retained for further analysis. This was decided following discussions with relevant stakeholders, and on the basis that funding had already been earmarked for watershed management, including reforestation of water catchment areas, at the national level. Consequently, the 3 prioritised adaptation technologies that were retained for further analysis were:

1. **Up-scaling of locally proven IPM technologies for control of pest of economic importance:** to minimise on use of chemical pesticides and reduce risk of damage by pest and diseases;
2. **Micro irrigation (gravity fed drip & mini and micro sprinkler irrigation)**: to optimise use of irrigation water, improve on crop productivity and reduce risk of crop damage by drought among small scale farmers; and
3. **Decentralised rapid pest and disease diagnosis service (plant clinic)**: to provide a rapid and reliable pest and diagnosis service to enhance farmers' ability for damage due to pest and disease and thus improve productivity and quality.

Step 8. Sensitivity analysis

The chosen criteria may be assigned different weights, or different scores for technology options may be used, for example if there were disagreements between sector working group members in choosing criteria. The MCA process of filling out the decision matrix can be repeated different weights or scores to reflect these different opinions.

Also, technologies may score differently under different scenarios, and it would be useful to estimate the performance of the technologies based on e.g. different climate scenarios and different time scales, and run the MCA process for these scenarios accordingly.
The multiple timeframes could be:

- Short term: 2030

- Medium term: 2050
- Long term: 2100

Sensitivity analysis
In order to investigate the sensitivity of technology ranking on allocated weights, the weight assigned to each criterion was reassessed by taking into consideration any uncertainty and conflicting objectives of multiple stakeholders. Hence, the ranking of adaptation technologies was carried out for different sets (or cohorts) of weights. Based on the sensitivity analysis, the overall ranking of the adaptation options was finally agreed upon by all stakeholders and technical experts

Chapter 3. Criteria identification and assessment

The objective of this chapter is to assist technical experts and decision-makers in how to select appropriate criteria for prioritizing and assessing adaptation technologies in the context of broader economic, environmental and social development objectives. It aims to support work on technology needs assessments using MCA for prioritizing technologies but can also be applied in other contexts.

The criteria are aimed to cover the aspects deemed necessary for performing a robust multi-criteria analysis for technology needs assessment. Following MCA4Climate from UNEP (2011), a multi-criteria tree of criteria is shown in Figure 1. At the first and second levels there are inputs which characterise the costs or spending involved with technology transfer and the outputs which are the range of economic, social, political/institutional, environment, climate-related and technology-related set of criteria used for evaluating the technology alternatives. The third level shows the specific criteria for each area of evaluation and these criteria are meant to be generic enough to be applicable to evaluation of adaptation technology alternatives in the main sectors for technology needs.

In this chapter, each third-level criteria category is broken down by sector and where applicable, are given sector-specific criteria that relate to technology transfer. The focus is on 4 main sectors, agriculture, water, coastal and health. These sectors were chosen as criteria were compiled from past TNA reports, and these sectors were the most prominent in climate adaptation related technology needs. Other examples of Multi-criteria analysis, mainly the MCA4Climate by UNEP (2011) also contributed to the development of this comprehensive list of criteria. For users who would like to utilise a more complex and comprehensive MCA tool for climate policies, they are referred to the MCA4Climate tool[2].

In addition to this guidance, an Excel MCA spreadsheet has been developed where the criteria have been built in, so that users can choose criterion according to sector, and will include a function for ensuring mutual independence of preferences (i.e. ensuring criterion are independent of each other). *[more on the spreadsheet when finished]*

[2] http://www.mca4climate.info/

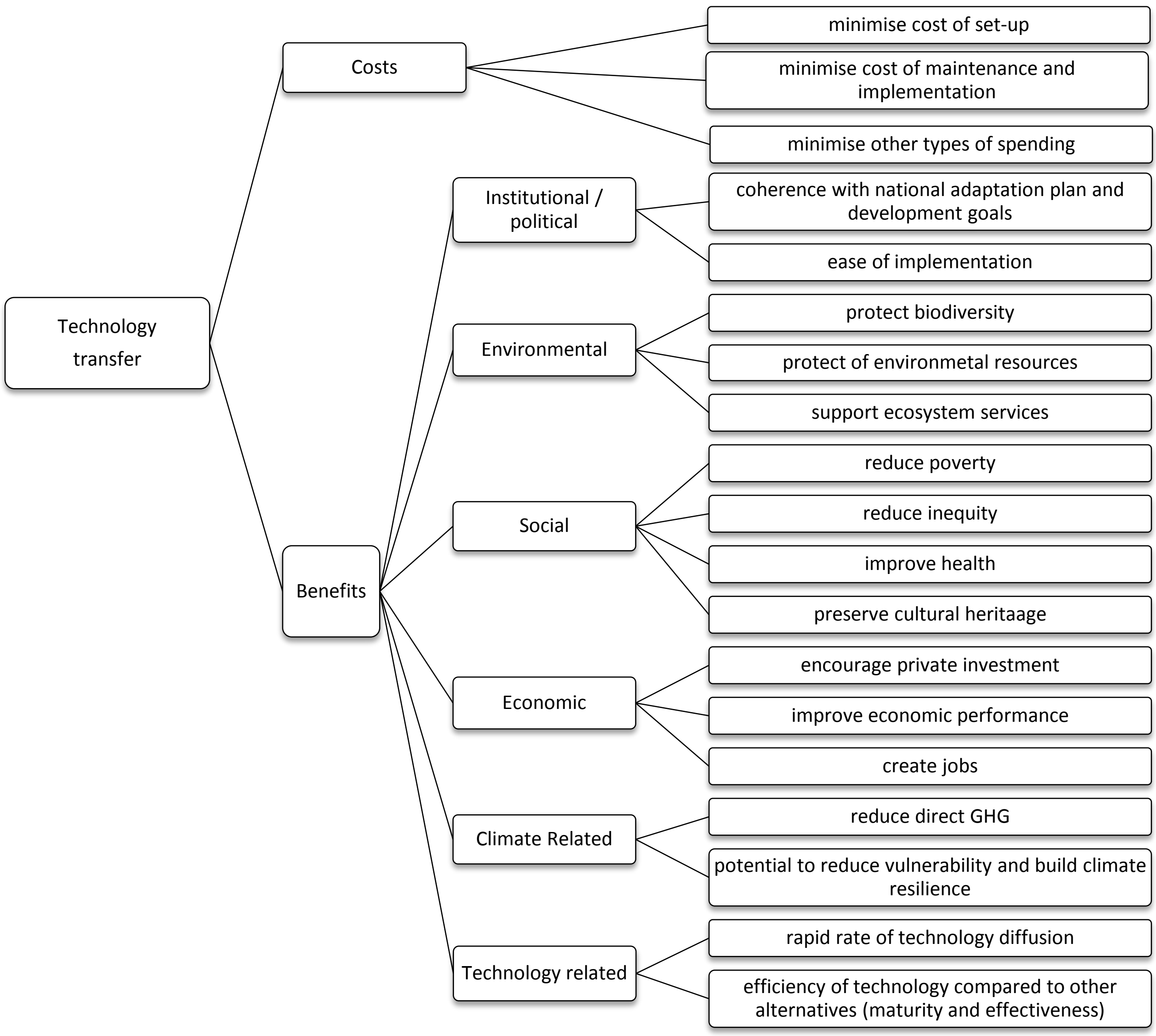

Figure 1 MCA criteria tree (adapted from MCA4Climate UNEP, 2011)

3.1 Cost

This group of criteria encompass the inputs that are expected to be associated with technology transfer. Costs of technology transfer are a major factor when choosing technology alternatives and need to balance by the benefits obtained from the alternatives. Seen in isolation, a preferred alternative may be one that had a minimum cost of set-up, minimum cost of maintenance and implementation, and also one that minimised the spending in other areas that would be necessary to allow the technology to be implemented (i.e. costs of setting up the enabling framework).

Criterion 1: Minimise cost of set-up

This criterion looks at the costs of set-up of the technology often incurred during start-up phase and can be applied for adaptation technologies for any sector. Set- up costs of a technology are usually the highest as they can often involve associated costs of importing a technology, installing it (and thereby relying on resources that may not be available in-country), or with technologies already in country these could be costs of replicating in other areas. Criteria can include per unit cost, which can be obtained from the technology supplier accounts, costs of importation (e.g. taxes) which can be derived from government accounts, costs of installation which can be calculated from labour used in installing the technology, and other transaction costs that could include community consultation, government permits, training of local people to use the technology etc.

Sector	Criteria	Data sources / methods
Water, agriculture. coastal, health	• capital cost per unit of technology • costs of importation (e.g. taxes) • cost of installation	• accounts from technology supplier • estimated labour and resource costs from relevant accounts associated with installation and importation

Criterion 2: Minimise cost of maintenance/ implementation

This criterion will cover the running costs of the technology over time, which encompasses the implementation costs as well as the maintenance of the technology. These costs need to be calculated over the lifetime of the technology and an appropriate <u>discount rate</u>[3] should be used to compare current and future values. This also needs to incorporate transaction costs associated with the research, design, support and monitoring of the technology. Appropriate criteria to measure this can be split up by sector, as in the following table. In the water sector, for example, a criterion could also be the average annual storage volume or the critical month storage volume which is not a cost item but rather a capacity criterion.

For agriculture the cost per unit of increased yield reflects the marginal cost of the output from the technology, and can be calculated from yield data collected from a variety of methods specified below. In the coastal sector, costs of infrastructure investment allocated to coastal technology development in other regions could be examined. If the coastal technology is new then cost per unit area protected from flooding can be used.

[3] see guidance note on economic assessment of adaptation for discussion on discount rate

Sector	Criteria	Data sources/ methods
Water	• costs of operation • costs of maintenance • costs per unit of storage capacity • average annual/critical month storage volume	• accounts from technology supplier • technology specifications
agriculture	• costs of operation • costs of maintenance • cost per unit of increased yield	• accounts from technology supplier • yield data from agricultural technology provider / primary data collection / expert judgement
coastal	• proportion of total government infrastructure investment allocated • cost per unit area protected from flooding	• costs in government budgets • expert panel for qualitative judgement
health	• costs of operation • costs of maintenance	• accounts from technology supplier

Criterion 3: Minimise other types of spending in absence of climate technology and/or to create an enabling framework

In the absence of climate adaptation technologies, climate impacts are likely to affect local people a lot harder, which will involve spending in other sectors to cope with that impact. One example is in the agricultural sector, where reduced rainfall from climate change can cause crop failure and thereby lead to the need for government spending to support people who are facing food shortage.

Moreover, for any technology alternative to be successfully adopted, spending associated with created an enabling framework (both physical and regulatory) is necessary but ideally not large. Thus, this criterion looks at how to minimise the all financing needs required from the public purse in order to support the introduction of the climate adaptation technology and all the costs associated with not implementing the adaptation technology. Examples per sector of other types of spending are given below, along with criteria to measure them.

Sector	Criteria	Data sources/ methods
Water	• investments in water management infrastructure • costs of supporting conflict resolution • costs of supporting management institutions • cost of implementing a water policy reform, including enforcement of water rights • costs of additional monitoring and analysis of aquatic ecosystems	• government budgets in water management • expert panel judgement • expert panel judgement • expert panel judgement/ government budgets • expert panel judgement / current budget allocations to monitoring
agriculture	• costs of maintaining emergency food stocks • costs of supporting conflict resolution • costs of supporting management	• expert panel judgement/ costs during previous food shortages (government) • expert panel judgement • expert panel judgement

	institutions • cost of implementing agricultural policy reform	• expert panel judgement/ government budgets
coastal	• costs of strengthening coastal management capacity/ institutions • cost of implementing coastal policy reform	• government budgets/ accounts/ operational costs for coastal management institutions • expert panel judgement/ government budgets
health	• costs of strengthening the health system • costs of health vulnerability assessments • costs of education of personnel in adaptation and resilience • costs of managing disease outbreaks	• expert panel judgement/ government budgets • expert panel judgement/ costs during previous disease outbreaks

3.2 Benefits

The following group of criteria encompass the benefits associated with the climate technology transfer. These move beyond the quantifiable economic benefits, which are a trademark of the cost-benefit analysis, but aim to encompass other areas such as institutional and political criteria, environmental, social, climate-related, and technology related criteria. Specifically, it is these "softer" criteria that will be judged and evaluated by expert working groups during the MCA process so that they can be made comparable to quantitative costs and benefits.

3.2.1 Institutional / Political criteria

This group of criteria look at the institutional and political factors associated with the decision to choose one particular adaptation technology over another alternative. A technology alternative should ideally be coherent with the country's national adaptation plan and national development goals. This is to ensure that technology transfer actions are streamlined with the priorities set by the government in their national adaptation plan, and in working towards their development goals. Furthermore, introduction of new technologies should not require an overhaul of current regulatory and physical infrastructure. Thus, as many regulations and laws supporting a technology alternative should already be in place to support ease of implementation.

Criterion 1: Coherence with national adaptation plan and development goals

The national adaptation plan (NAP) is a participatory and iterative national process to identify medium- and long-term adaptation needs and development and implementing strategies and programmes to address those needs (UNFCCC, 2015). Therefore it is imperative for the choice and implementation of climate adaptation technology to be aligned to this plan. Similarly, the technology should ideally work together with meeting the development goals set by a country. As a result, appropriate criteria are the degree of coherence with the NAP and development goals.

Sector	Criteria	Data sources/ methods
Water, health	• degree of coherence with national adaptation plan • degree of coherence with national	• expert panel for qualitative judgement

	development goals	
agriculture, coastal	• degree of coherence with national adaptation plan • degree of coherence with national development goals • type, length and security of land tenure and use rights	• expert panel for qualitative judgement

Criterion 2: Ease of implementation

Existing regulations and policies should ideally be in place before launching a new technology to ensure ease of implementation and ensure that rate of diffusion of technology is supported (see Criterion 6.2). Often, having existing regulations and policies in place also means that local communities are familiar with them. Within this criterion, utilisation of local resources is also a factor. As mentioned under cost criteria, having the technical capacity in-country to set up and implement a technology would be advantageous and dismiss the need for hiring costly external experts.

Sector	Criteria	Data sources/ methods
Water, agriculture, coastal, health	• no. of laws / regulations supporting technology • no. of amendments in regulatory frameworks needed • degree of community acceptance • no. of people with local capacity	• analysis of policies • expert panel for qualitative judgement

3.2.2 Environmental criteria

Environmental benefits need to be carefully considered when choosing technology alternatives. Environmentally detrimental technologies work against protecting the integrity of nature and its resources and therefore aspects such as biodiversity protection, protection of environmental resources and support to ecosystem services need to be considered.

Criterion 1: Biodiversity protection

Technologies must ensure the protection of biodiversity in the actual area of implementation and in the surrounding habitats. In agriculture, this includes the diversity of e.g. seeds and livestock breeds. In water and coastal areas, this could include diversity of species found in the areas. The diversity of surrounding habitats and environments will also be relevant for these three sectors. Incorporated under this criterion will be habitat protection, as often protection of biodiversity necessarily entails protection of habitats.

Sector	Criteria	Data sources
Water, Coastal	• no. of species • area (ha) under protection • no. of conservation policies	• biodiversity monitoring data
Agriculture	• no. of species in surrounding	• biodiversity monitoring data

	habitats • no. of local seed varieties used • quality of natural habitats and ecosystem around agricultural areas	• quality judgement by expert panel
health	n/a	

Criterion 2: Protection of environmental resources

Technologies can often affect surrounding natural resources and oftentimes draw on these resources to function effectively e.g. rainwater harvesting technologies could affect the natural water cycle affecting groundwater levels. The environmental quality and integrity therefore needs to remain intact, and at best improved following the introduction of the technology. There are several criteria to measure this:

Sector	**Criteria**	**Data sources**
Water	• ground water quality and quantity • surface water quality and quantity • reduced degradation from run off	• environmental monitoring data
agriculture	• reduced rate of soil erosion/ run off and sedimentation • reduced area of land lost / degraded due to inundation, salinity • changes in ground water levels • water and air quality	• environmental monitoring data
coastal	• coastal erosion reduction • area of coastal habitat protected	• coastal monitoring data
health	• air quality	• environmental monitoring data

Criterion 3: Support to ecosystem services

This criterion assesses how the given technology contributes to supporting ecosystem services - broadly categorised into provisioning, regulating, supporting and cultural services. Provisioning services relate to the production of food and water. Regulating services relate to regulation of climate and disease/pest control. Supporting services relate to nutrient cycles, seed dispersal, and pollination, where cultural ecosystem services relate to the spiritual and recreational benefits. Across the sectors, criteria can vary as ecosystem services provided in these habitats are distinctly different.

Sector	**Criteria**	**Data sources/ methods**
Water	• extent of purification of air and water • ground /surface water quality and quantity	• remote sensing analysis of changes to extent and quality • Qualitative judgements by experts on future trends
agriculture	• changes in crop pollination • changes in pest and disease • changes in seed dispersal • changes in waste decomposition	• remote sensing analysis of changes to extent and quality • Qualitative judgements by experts on future trends

	• changes in purification of air and water	
coastal	• coastal aquatic system quality and extent • changes in ecosystem services due to coastal management policies	• Modelling • Qualitative judgements by experts on future trends
health	(indirect benefits)	

3.2.3 Social criteria

This set of criteria address the social aspects that must be considered when choosing a technology alternative. Since adaptation to climate change affects society, technologies to remediate impacts should also leave positive benefits for the local population. These could encompass effects that contribute to poverty reduction, inequity reduction, improvements to health, and preserving cultural heritage.

Criterion 1: Reduction of poverty

Technologies in their implementation can affect the welfare of local people. This criterion assesses the effect of technologies in achieving poverty reduction of the communities and households affected if the climate technology is implemented. Although the effect may not be direct, it is important to ensure that effects are at least not causing more households to fall under the poverty line, and at best bringing people out of poverty. Poverty here is measured in various dimensions including income poverty, access poverty, and asset poverty and can be measured by comparing data collected in national census e.g. percentage under poverty line, income per capita to forecasts on future trends along these criteria.

Sector	Criteria	Data sources/ methods
Water, agriculture, coastal	• percentage of population under poverty line • income per capita • no. of jobs created • no. and size of farms (access to land) • no. of landless (access to land) • no. of hh with access to clean water (access to water) • no. of hh and area with irrigation (access to water) • changes in asset wealth	• Socio-economic data (e.g. census) • Qualitative judgements by experts on future trends
health	• (all of above) • no. of hh with access to healthcare services • decline in spending on treating diseases	

Criterion 2: Reduction in inequity

In the same vein as the poverty reduction criterion, chosen technology alternatives should aim to reduce inequity between social classes, gender, ethnic groups etc. In particular it looks at income disparities and differences in access to resources between these groups. Again socio-economic data from e.g. a national census could be an important source of information and this could be disaggregated by groups to see what the baseline situation is like. This data can then be compared to forecasts made by experts on future trends following technology introduction. Since these criteria overlap with the criteria under the poverty reduction criterion, the user will need to choose between one of these two criteria. Alternatively, the criterion using the Gini coefficient for different groups could be the main criterion to evaluate the reduction in inequity, and other criteria can be used to judge reduction in poverty.

<table>
<tr><th>Sector</th><th>Criteria</th><th>Data sources/ methods</th></tr>
<tr><td>Water, agriculture, coastal</td><td>• percentage under poverty line
• income per capita
• no. of jobs
• number and size of farms (access to land)
• number of landless (access to land)
• no. of hh with access to clean water (access to water)
• no. of hh and area with irrigation (access to water)

• Gini coefficient for groups</td><td rowspan="2">• information can be compared using socio-economic data (e.g. census) between:
- poor and rich
- gender
- different ethnic groups
- rural urban
• Qualitative judgements by experts on future trends

• economic analysis of Gini by experts</td></tr>
<tr><td>health</td><td>• (all of above)
• no. of hh with access to healthcare services
• extent of spending (in health) between groups</td></tr>
</table>

Criterion 3: Improvements to health

This criterion is associated with health improvements to the population that is affected by the technology improvements. Such technology should ideally reduce morbidity and mortality rates resulting from climate change. Moreover, in the agricultural sector, it should lead to increased per capita food availability and reduced share of undernourished in the total population.

<table>
<tr><th>Sector</th><th>Criteria</th><th>Data sources/ methods</th></tr>
<tr><td>Agriculture</td><td>• increased per capita food availability
• reduced share of undernourished in total population
• changes in human health (morbidity and mortality rates)</td><td rowspan="2">• socio-economic data and statistics (e.g. census)

• qualitative judgements by experts

• health statistics</td></tr>
<tr><td>Water, coastal, health</td><td>• changes in human health (morbidity and mortality rates)</td></tr>
</table>

Criterion 4: Preservation of cultural heritage

Cultural heritage is an important part of human history which has been formed over centuries by local populations. Introduction of new technologies, for instance softer technologies as well as spread of newer hard technologies may erode cultural and traditional practices. Importantly coherence and preservation of culture and traditions may facilitate implementation of some of these technologies.

Sector	Criteria	Data sources/ methods
agriculture	• no. of traditional animal breeds, fruit, crop varieties • coherence with customary use rights • participation rate of indigenous people	• agricultural data • socio-economic data (e.g. census) • qualitative expert judgement
water, coastal	• degree of utilisation of customary technologies and methods • coherence with customary use rights	• qualitative expert judgement
health	• coherence with customary medicinal plant use • degree of utilisation of local medicinal plants and local healing knowledge	• qualitative expert judgement

3.2.4 Economic criteria

Economic criteria represent the flipside to cost criteria in that they represent the economic benefits to be gained from choosing technology alternatives. Ideally climate adaptation technologies will encourage private investment to spur local innovation and ensure financial sustainability of the product. It should improve general economic performance in that sector, that result from increasing productivity and market development, and also lead to job creation.

Criterion 1: Encourage private investment

Private investment in the technology is essential to ensure the financial sustainability of the technology and its use. This will ensure that the costly burden of maintaining, implementing and replacing technologies do not fall on the public budget but instead that the technology can attract sufficient interest and investment to spur local innovation and technology development. the amount of private investment that technologies are likely to attract can be calculated on the basis of exiting private sector investors in the sector and similar reported investments.

Sector	Criteria	Data sources/ methods
Water, agriculture, coastal	• amount of private investment / funding	• feasibility study with existing investors • reported investments • qualitative scaling by expert panel
health	• amount of private investment / funding in primary healthcare services, hospitals	

Criterion 2: Improve economic performance (productivity, market development)

Generally technologies should aim to improve economic performance in that sector. This includes aspects of increasing productivity as well as generating interest and demand in the market for its output. This criterion thus encompasses all of these factors and works towards ensuring that outputs remain or are more competitive vis-à-vis alternatives.

Sector	Criteria	Data sources/ methods
Water	• changes in damages to value of economic activity	• qualitative judgements by experts

agriculture	• changes in agricultural productivity as measured by: • total output and production per unit area • net revenues from crop yields per unit area • changes in markets for agricultural products	• modelling from statistics • qualitative judgements by experts
coastal	• changes in productivity of coastal-based industries • changes in markets for coastal-based products	• economic analysis under different coastal management policies/technology options, or • qualitative judgements by experts
health	• changes in productivity due to reduced ill days • changes in economic output due to reduced ill days	• qualitative judgements by experts • public accounts

3.2.5 Climate-related criteria

Climate-related criteria are vital to consider when choosing technology alternatives as the very aim of technology transfer is to mitigate the impacts of climate change. The two main criteria encompass the adaptation and mitigation potential of climate technologies. specifically these are the potential for the technology to reduce vulnerability and build resilience amongst communities to climate impacts and any reduction in direct greenhouse gases.

Criterion 1: Potential for vulnerability reduction and climate resilience

Adaptation to climate change works towards reducing the vulnerability of populations facing climate change and building their resilience to cope with the impacts. This can be achieved through e.g. strengthening current standards of living so that in the face of adversity, households may be able to cope with the climate shock. it touches upon the financial capabilities of affected populations (income and assets), but it also encompasses the development of social safety nets and other insurance mechanisms that will also help households recover from shock and in this aspect is tied closely to the social criteria e.g. poverty reduction.

Sector	**Criteria**	**Data sources/ methods**
Water	• no. of households with access to clean water • area not damaged by flooding • capacity of water storage • no. of households with financial capability and social networks to cope with shocks	• socio-economic data (e.g. census) • data on city infrastructure • qualitative expert panels
agriculture	• no. of households not experiencing crop losses • no.of households not experiencing crop disease • extent of crop and livestock diversification • no. of households with financial capability and social networks to cope with shocks	• agricultural data • socio-economic data (e.g. census) • qualitative expert panels

coastal	• area not damaged by flooding • no. of households with financial capability and social networks to cope with shocks	• qualitative expert panels
health	• no. of hh with access to health services • no. of health services available • extent of early warning systems for infectious diseases • no. of households with financial capability and social networks to cope with shocks	• socio-economic data (e.g. census) • data on infrastructure • qualitative expert panels

Criterion 2: Reduction of direct greenhouse gases (GHG)

This criterion is an essential criterion when evaluating climate technologies in general, and even though the focus in this guidance is on adaptation technology, the achievement of joint adaptation and mitigation benefits from any given climate technology is advantageous. This is therefore considered an important criterion in the evaluation of alternatives, as the opportunity to achieve synergies between adaptation and mitigation should not be overlooked.

Sector	**Criteria**	**Data sources/ methods**
Water	• changes in net carbon footprint (emissions from implementation - increases in carbon capture)	• GHG emissions budgets • qualitative expert panels
agriculture	• changes in net carbon footprint (emissions from implementation + emissions from agricultural activity - increases in carbon capture of agricultural systems)	
coastal	• changes in net carbon footprint (emissions from implementation + emissions from coastal activity - increases in carbon capture of coastal systems)	
health	• changes in net carbon footprint of health services	

3.2.6 Technology-related criteria

This particular set of criteria has been developed especially for the MCA in Technology Needs Assessment and covers basic elements of technology transfer. Assuming that climate technologies should be readily accepted and dispersed within the affect population, rate of technology diffusion which is tied closely to farmer acceptance is a crucial criterion to consider. Moreover, the technology's efficiency in relation to other alternatives must also be considered and the main aspects that are examined here will relate to the technology's maturity and effectiveness in helping populations adapt to climate change

Criterion 1: rate of technology diffusion/ farmer acceptance

This criterion measures the rate of technology diffusion or spread in the target population. This can be measured through analysing the proportions of targeted users using the technology over the following years. Other criteria could include the degree of coherence or similarities to existing technologies and traditions, and ties closely to criterion 3.4 on preservation of cultural heritage.

Sector	Criteria	Data sources/ methods
Water, agriculture, coastal, health	• proportion of targeted users using technology (no. of targeted users / no. of users introduced to technology) after first year • proportion of targeted users using technology (no. of targeted users / no. of users introduced to technology) after second, third year • degree of coherence with existing technologies/ traditions	• Primary data collection • qualitative judgement by expert panels

Criterion 2: efficiency compared to other alternatives (maturity, effectiveness)

The maturity of a technology will closely link to how efficient and effective the technology is in achieving the desired results. Technologies which have been tried and tested in other regions can often be less problematic to implement than other regions. That being said, tried and tested technologies may not achieve the same effectiveness as newer technologies in helping communities overcome impacts of climate change.

Sector	Criteria	Data sources/ methods
Water, agriculture, coastal, health	• extent of technology maturity • effectiveness in achieving desired effect/ output	• qualitative judgement by expert panels

4 References

CIFOR (1999) Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and Indicators. 9. The Criteria & Indicators Toolbox Series. Center for International Forestry Research (CIFOR). Available at: http://www.cifor.org/livesinforests/publications/pdf_files/toolbox-9c.pdf

Dodgson, JS, Spackman, M, Pearman, A and Phillips, LD (2009) Multi-criteria analysis: a manual**.** Department for Communities and Local Government: London. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7612/1132618.pdf

UNFCCC (2002) Annotated guidelines for the preparation of National Adaptation Programmes of Action. Least Developed Countries Expert Group. Available at: http://unfccc.int/resource/docs/publications/annguid_e.pdf

Ministry of Environment, MoE (2012) Lebanon Technology Needs Assessment report for Climate Change. Ministry of Environment, Beirut

UNEP, 2011. MCA4climate. Online at: < http://www.mca4climate.info/>

Annex A. Example of Technology Fact Sheet

Technology: Drip Irrigation	
Sector : Agricultural	
Subsector : water management for crop production	
Technology characteristics	
Introduction	Systems of pressurised irrigation can improve water efficiency and contribute substantially to improved food production. Sprinkler irrigation is a type of pressurised irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. Drip irrigation is based on the constant application of a specific and calculated quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the root area and applying it under particular quantity and pressure specifications.
Technology characteristics/highlights	Few bullet point, i.e. low/high cost, advanced technology, low tech, • High initial costs if the water source (e.g. well or borehole) is to be established at the same time • The technology is adequate for current as well as future climate, and has significant potential to reduce small farmers' vulnerability to increase variability in rainfall and prolonged droughts. • Maintain crop yields, income and jobs in the agricultural and food processing sectors
Institutional and organizational requirements	Investment will be required to build workers capacities in order to accurately manage maintenance and water flow control.
Operation and maintenance	The drip tape or tubing must be carefully maintained in order to avoid leaking or plugging and emitters must be regularly cleaned to avoid blockage from chemical deposits. In certain cases, it would be necessary to redesign the farm weed control programme
Endorsement by experts	It is a widely acknowledge technology among agricultural experts

Adequacy for current climate	The technology is adequate for current as well as future climate. However, drip irrigation is more appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use. However, the drip technology uses even less water than e.g. sprinkler irrigation, since water can applied directly to the crops according to plant requirements. Furthermore, the drip system is not affected by wind or rain (as is the sprinkler technology).
Scale/Size of beneficiaries group	Large potential in the country
Disadvantages	The initial cost of drip irrigation systems can be higher than other systems. Final costs will depend on terrain characteristics, soil structure, crops and water source. Higher costs are generally associated with the costs of pumps, pipes, tubes, emitters and installation. Unexpected rainfall can affect drip systems either by flooding emitters, moving pipes, or affecting the flow of soil salt-content. Drip systems are also exposed to damage by rodents or other animals. It can be difficult to combine drip irrigation with mechanised production as tractors and other farm machinery can damage pipes, tubes or emitters.
Capital costs	
Cost to implement adaptation technology	The technology is widely variable, however the cost of a drip irrigation system ranges from US$ 800 to US$ 2,500 per hectare depending on the specific type of technology, automatic devices, and materials used as well as the amount of labour required. Financing for equipment may be available from financial institutions via leasing operations or direct credit. Farmers usually cover installation, design and training costs that represent about 30 to 40 per cent of final costs depending on the size of the land, characteristics and shape, crops, and particular technology applied.
Development impacts, direct and indirect benefits	
Reduction of vulnerability to climate change, indirect	Avoided impacts include maintenance or even increase in current crop yields. Income for small scale farmers will be maintained, as well as job opportunities, both in the agricultural and food processing sector
Environmental benefits, indirect	Reduction in GHG emissions, local pollutants, ecosystem degradation.
Local context	
Opportunities and Barriers	<u>Barriers:</u> Drip irrigation technology faces some possible barriers to implementation including lack of access to finance for the purchase

	of equipment, a higher amount of initial investment involved than other systems, and limited market for repurchased equipment. Even though several suppliers with wide experience may exist, these firms are usually focused on large land extension projects and do not cater for small and medium-sized farmer markets. Technical conditions such as soil clay presence, irregular rainfall or steep slopes can increase implementation and maintenance costs or affect drip system efficiency. Also, the yield of existing crops irrigated by gravity or another open system can be affected by changing to drip system. <u>Opportunities:</u> Drip irrigation is particularly suitable for use with ground water from wells. It requires institutional arrangements and capacity building of water users to avoid an overuse of aquifer resources and potential conflicts. Drip irrigation technologies can be implemented via a water user association to improve economic benefits and reduce initial investment costs. Drip irrigation is a versatile technology suitable for application in a wide range of contexts. It can be implemented at small or large scales and with low-cost or more sophisticated components. This technology can be employed in conjunction with other adaptation measures such as the establishment of water user boards, multi-cropping and fertiliser management. Promoting drip irrigation contributes to efficient water use, reduces requirements for fertilisers and increases soil productivity. It is particularly suitable in areas with permanent or seasonal water scarcity, since crop varieties to plant can also be adaptable to these conditions.
Market potential	It has a nationwide potential
Status	Limited to large scale farmers
Timeframe	Short Term: ready for implementation
Acceptability to local stakeholders	There is no reluctance among stakeholders with regards to drip irrigation technology