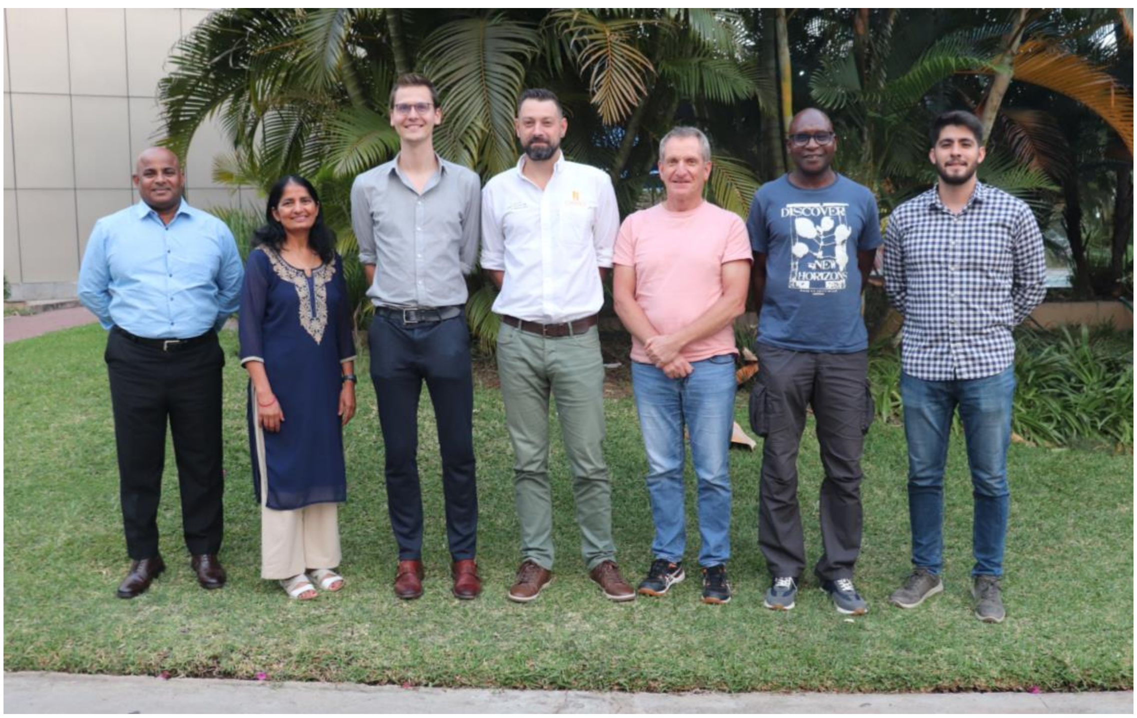
INNOVATE – 3.5 Community of practice on Scale Appropriate Mechanization

WORKSHOP REPORT

"Mechanization in EiA Working Group Meeting 2023"



Lusaka, Zambia – 12-13 September 2023

Specific meeting objectives:

1. Defining thresholds of climate-smart machinery solutions from a context-specific and scale-appropriate perspective.

2. Develop a framework around what can farm machinery could be considered climate smart, in order to develop a tool that could facilitate scoring different machines on a climate-smart rating, across different production systems around the world.

Day 1 – Introduction: welcome and presentation of the objective of the workshop

Session 1) Introducing the "Climate-smart machinery" concept and publication – Jelle Van Loon.

- Machines inherently do something more efficient—they streamline labor and handle time-related constraints.
- Historically, machinery has made it possible to increase the productivity of agricultural activities and allow farmers to be more precise in their operations.
- Climate change affects agricultural systems: erratic rains, drought, floods, etc. Climatic opportunity windows are shorter compromising production. We need climate-smart solutions.
- It is normal to ask ourselves, how do climate-smart methods help with climate adaptation and future climate change mitigation? Can machines play a role in enhancing food security in a sustainable way while mitigate climate change?
- From our perspective, the adoption of suitable agricultural machinery could play an important role in mitigating climate change by improving productivity while reducing greenhouse gas emissions.
- We hope climate-smart machinery can help to reduce GHG emissions in agriculture.
- There is a need to define the thresholds that can differentiate conventional machines from climate-smart machines.

Session 2) Discussion and Q&A

During this session, participants discussed the word "smart" since may generate some confusion with the "smart technologies" concept, leading to the next:

- To avoid misunderstandings, there was a need to establish the difference between "smart farming" and "climate smart agriculture" (Figure 1)
- Smart farming refers to the use of technologies as big data, automation, artificial intelligence, internet of things (IoT) and robotics to improve the quality of agricultural produces, meanwhile climate-smart agriculture is a new approach to manage landscapes to help to face the challenges of climate change.
- The word "smart" could lead to intelligent systems, or intelligent machinery.
- There are smart farming solutions that belong to climate-smart agriculture, but not necessarily backwards.

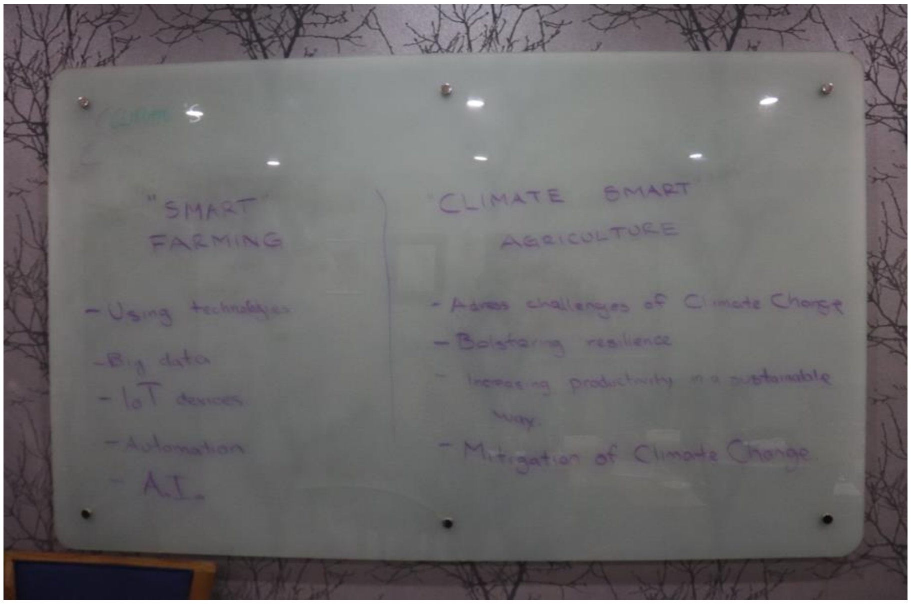


Figure 1. Differences between smart farming and climate-smart agriculture.

Starting from the definition of Climate Smart Agriculture (CSA) from the Food and Agriculture Organization: CSA is "a strategy that seeks to address the challenges of food security and climate change by bolstering resilience, reducing GHG emissions, increasing productivity in a sustainable way, and enhancing achievement of food security". During this session it was established that those four aspects of CSA can be used as a baseline for what Climate Smart Machinery (CSM) could be.

The four main aspects of CSM would be then:

- Bolster resilience.
- Reduce GHG emissions.
- Increase productivity in a sustainable way.
- Enhance achievement of food security.

Before getting into the thresholds, there was a brainstorming session to settle the characteristics that were necessary to consider in order to try to define an index. These were the results:

- The dimension of labor availability, skilled labor and automation towards precision
- Climate vulnerability: Whether we are working in rain fed versus irrigated areas
- Topography: Whether we are working on flats or valleys versus slope areas.
- Scale or size of operation: small, medium or large
- The integration of different equipment in the system
- The greenhouse gasses emission. Low emission: both direct and indirect.

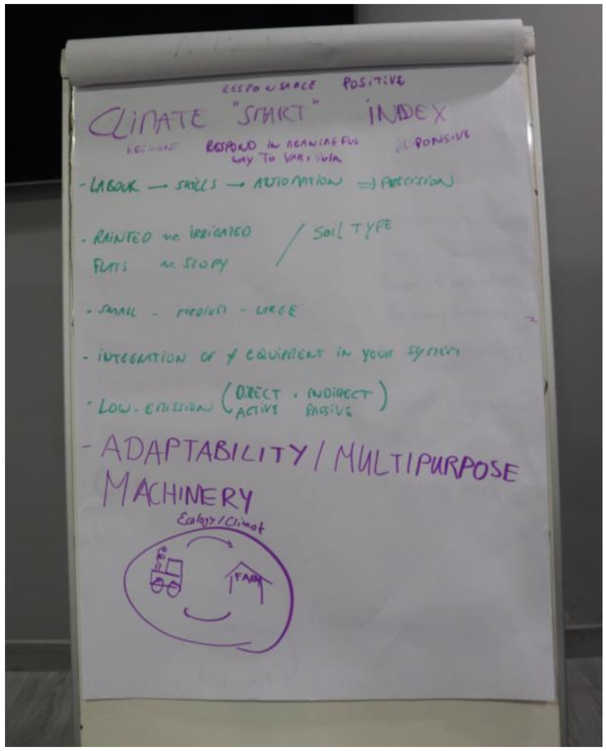


Figure 2. Characteristics to consider in order to try to define an index.

There was a quick discussion about the precise word to use for the index. Climate-smart index? Climate-responsive index? Climate-smart responsible index?

- Climate-responsive index. The term responsive refers to responding to a current situation or reacting quickly to climate change challenges with a positive outcome, which is adaptation. But CSM should not be adaptive only.
- Climate-responsible index. This refers to being aware of the obligations related to climate change. It is about trying to make the right choice for the coming future. Interesting point to mention.

In this part of the session, there was another brainstorming session where participants established the indicators that climate-smart machines should possess. These were the results:

Table 1. Main categories and sub-categories of the CSM indicators from a brainstorming session

Main categories	Sub-categories
Fuel efficient	Multi-crop/multi-purpose
Time responsive: Quick response	Precision in operation
Scale appropriate to the operation´s size	Ease of operation
Energy efficient	Reducing drudgery
The need for integration or standalone	Service providing models
Improvement of plant environment	Soil compaction?
Cost efficient	Water positive
	Reducing losses?
	Land productivity
	Labor productivity
	Capital productivity
	Water productivity
	Nutrient productivity

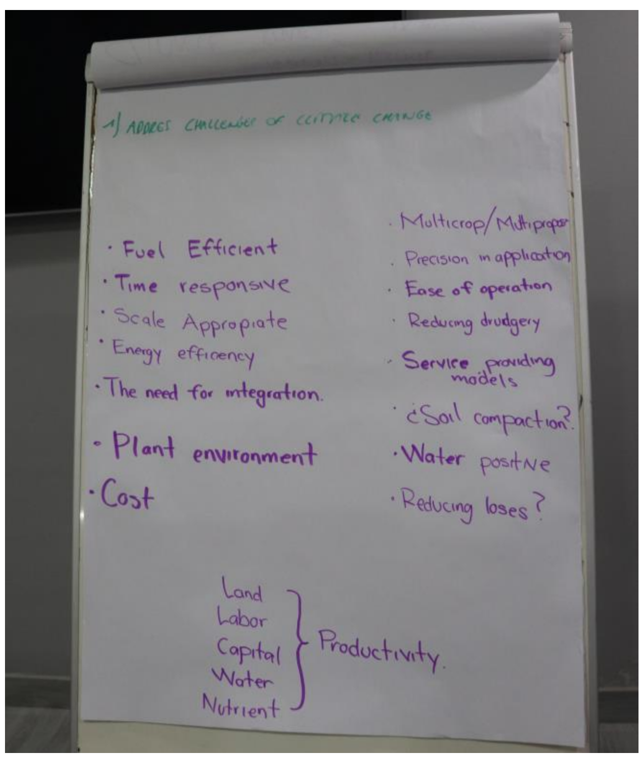


Figure 3. Possible indicators that CSM should possess.

Specific comments:

- Usually, we think that what determines the machine is the system but should not be in that way. Since the system might change over time, in a climate-smart approach a technology should be easy to change/adapt with the system.
- CSM should respond in a meaningful way to both climate vulnerability and climate variability.
- The machine itself is not resilient. It is the equipment that you use which can increase the system´s resilience.
- The CSM index should be something that people can understand and frame correctly, something that can answer the need to rate a machine.
- Scale-appropriate is not about how scalable the machinery is, it is about the correct size or scale of the operation to the farmer´s enterprise. It is related to context specific.
- Resilience is an outcome of implementing climate-smart machines or is it a characteristic?

Outputs and final comments:

- There could be a misunderstanding that all machines are climate-smart simply because they are timely and efficient. This perspective, while understandable, might overlook the essence of being climate-smart.
- To say if a machine is climate-smart is not a yes or no question. There exists a whole range of “smartness”. But under the categories settled during the brainstorm is possible to build the indicators for developing a measuring tool.
- There is necessary to reduce the list of climate-smart attributes.

Day 2 – Defining thresholds, climate-smart machinery index and groups sessions.

Session 1) Conventional vs. climate-smart machinery break-out session

In this first session of the second day, break-out groups were formed to work-out in gathering diverse perspectives to distinguish between conventional and climate-smart farming practices.

Previous session observations:

- The term “conventional” is used to describe the tools that are commonly found in the region for the specific task and crop.
- Another classification could be according to the machinery power: manual tool, two-wheel tractor and four-wheel tractor, for example.
- The groups should try to identify challenges and explore what it takes to transition from conventional towards climate-smart solutions.

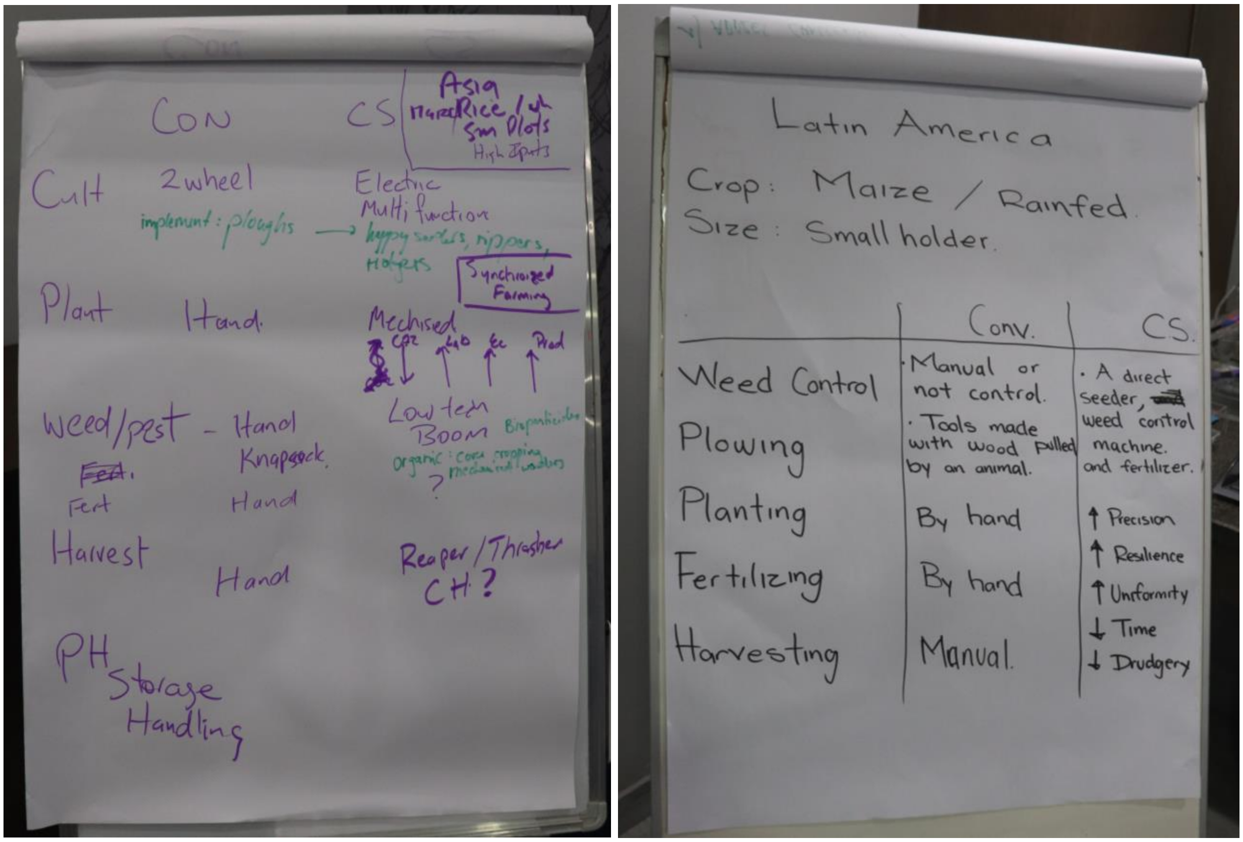


Figure 4. Results from the break-out groups session. Asia and Latin America.

<u>Group 1) Asia – Maize and rice rotation, small plots.</u>

a) For the cultivation:

- Conventional system
  - High inputs of fertilizers, pesticides, herbicides, etc.
  - Most of the cultivation is done now with machines like 2WT and using implements like ploughs.
- A climate-smart approach would be:
  - A multifunctional machine to do one pass, not two passes for cultivation and planting.
  - Different types of implements that could be developed to improve the efficiency of the cultivation.
  - Electric if possible
  - Possibly synchronized farming: synchronized seeding, harvesting, etc.

b) For the planting, the conventional system is majority done by hand. While a climate-smart approach would be a mechanized option that allows seeding and fertilizing.

c) For the weeding, fertilizing and pest control, the conventional system is hand and knapsack sprayers. While a climate-smart approach would be the use of boom sprayers, single-wheeled powered sprayers using biopesticides and electric mechanical weeders.

d) For the harvesting, in the conventional system is mostly done by hand. While a climate-smart approach would be the use of reaper, thresher and combine harvesters.

Group 2) Africa – Rice and wheat. Smallholder farmer

a) For land preparation, the conventional system is manual and animal draught for small scale or in bigger plots heavy tractors with accessories and land leveling. A climate-smart approach would be power operator tillage.

b) For the crop establishment, the conventional system is manual seeding, manual transplanting and conventional till seeders. While a climate-smart approach would be mechanical seeder and mechanical transplanters for replacing manual seeding, and no-till seeder for CA (multipurpose).

c) For the fertilizing, the conventional system is manual broadcasting. While a climate-smart approach would be a fertiseeder, which is a manual seeder cum fertilizer developed to micro-dose placement.

d) For the weeding, the conventional system is manual tools, hoe, stick or even by hand. A climate-smart approach would be the use of rotary weeders with no motor, only pushing tools.

e) For pest management, the conventional system uses manual sprayers. A climate-smart approach would be the incorporation of traps with some light or pheromones. This way is a small change, but it has a great impact in an ecological way.

Group 3) Latin America – Maize, rainfed, smallholder farmer.

a) For land preparation, the conventional system is animal draught with plow, sometimes even tools made of wood. A climate-smart approach would be the use of strip-till or some tool that promotes CA and minimizes soil erosion and increases resilience since you don't depend on an animal.

b) For crop establishment, the conventional system is by using a seeder attached to tractor. While a climate-smart approach would be a direct seeder/fertilizer implement. This allows the farmer to perform two tasks at a time and promote CA.

c) For fertilizing, the conventional system is manual broadcasting. A climate-smart approach would be a fertilizer spreader using, for example, a bike that increases the uniformity of the application. Or a fertilizer spreader that places the fertilizer directly into the soil.

d) For weeding, the conventional system is manual tools, like a hoe or a machete, and the use of pesticides with backpack sprayers. A climate-smart approach would be the use of rotary weeders to increase field capacity and reduce environmental pollution.

e) For harvesting, the conventional system is with hand tools in most cases, which is highly time consuming. While a climate-smart approach could be a combine harvester for a 2WT that performs the cutting, the crushing residues, the threshing, and packing, all at once.

Specific comments:

- It is important to recognize a scale in the index. For example, if the current situation is manual broadcasting fertilizing and you move to a fertilizer broadcasting, though still considered more conventional, represents a step toward greater precision and consistency in application.
- There is necessary to try to emphasize in which way the proposal is a climate-smart solution and not fall into being just a mechanized solution.
- It is important to consider the whole picture when proposing a climate-smart solution and try to not only focus on the increase of efficiency, uniformity, or field capacity, but also consider the CO_2 gasses emission changes.
- If you want to upgrade one machine from conventional to climate-smart, the level of integration or number of tasks performed is critical.
- Electrical and solar power can be an important thing to consider while talking about CSM.
- Some characteristics are a yes or no question and some items you must calculate them, like fuel consumption and field capacity.

Session 2) Challenges and barriers for developing and adopting a CSM index.

During this session, participants discussed the challenges and barriers for developing a CSM index, but also the challenges that can be faced when trying to adopt the index.

Specific comments:

- How can resilience be quantified? How can be quantified absorbative, adaptative and transformative capacities?
- It is necessary to identify which indicators are qualitative and can be answered as yes or no, and which, in a further instance, can or should be quantifiable.
- The land productivity, the labor productivity, the capital productivity, and water productivity can be quantified at some point?
- Using a radar chart would be the last goal for the indicators.

Most of the parameters are interconnected and do not necessarily fit into isolated categories. Rather than trying to fit parameters into specific categories, it is crucial to acknowledge that they have relevance and applicability among them. The challenge then becomes translating these interconnections into quantifiable indicators that can be validated systematically, considering their presence and significance throughout the entire range of parameters.

Additionally, the index must work for people without having to go through the effort of tedious calculations. At this point it is necessary to create a qualitative version, otherwise it will not give any quick results and will not be very practical.

Session 3) Group discuss identifying a climate-smart machinery score, based on the previous results.

During this session, participants discussed the indicators previously identified, and selected the ones that are key to use in the CSM index. Some of the points discussed were:

Carbon sequestration and greenhouse gases reduction

- Carbon sequestration consists of returning or capturing carbon to the soil, but to achieve that, it is necessary to improve soil health. For this reason, it was considered to add carbon sequestration to “plant environment”.

Fuel consumption, fuel efficiency and energy efficiency

- Fuel efficiency refers to the effective use of fuel by an engine, while energy efficiency takes a more comprehensive view, encompassing all the components necessary for an operation.
- A two-wheel tractor has higher fuel efficiency when compared to a four-wheel tractor, however the operation of a two-wheel tractor for extended periods of time demands a significantly higher amount of human energy.
- It was suggested to consider the fuel consumption into precision in application and do not include efficiency to simplify it.

Precise application, reducing drudgery, labor sensitive and labor productivity

- Labor is another farm input, but is not as easy to recognize as fertilizers, for example. For this reason, it was necessary to separate it from the term “farm input application”.
- Labor productivity refers to the labor-to-production conversion rate. Since these terms are broader, it was suggested to consider only “labor sensitive”.

Scale appropriate – The participants decided to delete it because it is assumed that the machine should fit in the specific context.

Figure 5. Participants discussing about the CSM indicators

The final list of the indicators and their respective description is the following:

Addressing challenges of climate change

Recently, the challenges of climate change often spin around responding to erratic weather patterns during the cropping cycle. Addressing challenges is about being responsive during the cropping cycle with our machines, and with that, try to tackle and adapt to the acute problems of climate change.

1) **Time responsive:** This aspect is inherently short-term and responsive. It is about addressing the immediate effects of climate change that you're currently witnessing. To succeed, you must be time-sensitive and appropriately scaled in your responses. For instance, if you need to hire a large combine harvester from a service provider but your field size doesn't match, you might find yourself at the end of the line, and that's not responsive enough to effectively cope with these challenges.
2) **Labor sensitive**: This refers to reducing drudgery, or if it is a response to labor availability versus land availability.
3) **Precision in application:** Being precise means to do it exactly as it should be done. This precision in application covers the aspects such as nutrients, water, fertilizers, seeds, fuel, and pesticides, which are commonly understandable as inputs by everyone.
4) **Reducing losses on/off farm:** This should include harvest and postharvest losses.
5) **Land management**: There are two points related to land management. If the machine can help with improved soil preparation and with improved topography management.

Mitigating climate change

Climate change mitigation is about being proactive rather than merely reactive. It is about being responsible for climate change and trying to mitigate it as a longer-term effect and transforming our environment for the better. For this reason, mitigation involves both direct/active and indirect/passive GHG emissions reduction.

6) **Plant environment**: Here, the focus shifts towards the future with a vision of creating a more sustainable and improved plant environment. This entails enhancing soil structure and organic matter, fostering soil's capacity for carbon sequestration, preventing compaction, and favoring looser. It includes if the machine promotes practices such as Conservation Agriculture (CA).
7) **Reducing GHG emissions**: This refers to the reduced fossil fuel use (fuel consumption), engine efficiency, the use of alternative renewable energy sources, good residue management (for avoid burning) and a reduced fertilizer volatilization by incorporating the fertilizer directly in the soil.

Bolstering resilience

Resilience is the ability to adapt to adverse situations with positive results. Example: A machine that breaks down quickly is less resilient than the one that resists more, or the ability to bounce-back quickly. To address the challenges of climate change, CSM seeks to bolster resilience by strengthening the three capacities: adaptive capacity, absorbative capacity and transformative capacity.

8) **Versatility:** This refers to the capacity of a machine to perform different tasks for different crops. This allows the farmer to engage in crop rotation and crop diversification. For example, a maize seeder that can be quickly adjusted to plant beans, is versatile. But also, if a machine allows the farmer to perform more than one task at a time, fulfill this.

An extra value here is whether the solution has its full benefits standalone or there's a need for integration. For example, laser-land leveler plus direct-seeder. The laser-land leveler standing alone has certain positive benefits, like better water movement and a smoother working area for all the other operations. But only using the direct seeder without laser-land leveling do not provide the full potential as combined.

9) **Maintenance needs**: This is about the lifespan of a machine. This includes the costs related to maintenance and spare parts. The more complex a machine is, the more likely it is to be hard to maintain, which can reduce the time responsiveness and lose flexibility.
10) **Ease of operation and the need for skilled labor:** This englobes the level of complexity to operate the machine, or the level of training for the operator to use it. If is an intuitive tool has an extra value. Nevertheless, once you overcome the skilled labor obstacle, it is possible to create resilience through service provision models.

After selecting these indicators, participants concluded that it was necessary to classify and weigh them according to their level of importance for CSM. To do this, each participant numbered the indicators on a board in order of importance where 10 was the highest score.

Figure 6. Participants numbering the indicators in order of importance.

The results for this activity showed that the three main indicators for a climate-smart machine, according to the participants, would be time responsiveness, greenhouse gas emissions reduction and precision in application.

Discussion point:

We understand that there is an extra dimension regarding environmental degradation, but this approach focuses on climate change. And it is important to consider that to enclose it, it is necessary to include some specific points, like the use of pesticides.

Index explanation

The index proposed is a tool for evaluating a machine and measuring the level of "climate-smartness" compared with the conventional machine that performs the same task. To do this, the evaluator must rate each of the parameters from -10 to +10, being +10 an optimum (or ideal) performance. Depending on the type of machine, some of the parameters will not have punctuation. The parameters are the following:

1) Address challenges of climate change

- Time Responsive
- Labor sensitive
- Precision in application
  - Seed deposition
  - Water-saving capacity
  - Improved nutrient management
  - Other inputs
- Reducing losses
  - Pre-harvest
  - During harvest
  - Post-harvest
- Land management
  - Soil preparation
  - Topography

2) Mitigation of climate change

- Plant environment
  - Microbiological health
  - Soil water holding capacity
  - Soil organic matter (for carbon sequestration)
  - Compaction (does it add to soil compaction?)
- Reduced GHG emissions
  - Improved fuel efficiency (reduced fossil fuel use)
  - Renewable energy sources (electric/solar)
  - Residue management (burning vs. non-burning)
  - Helps to reduce fertilizer volatilization

3) Bolstering resilience

- Versatility
  - Ability to handle different crops
    - Consecutive (crop diver) / Simultaneous (intercropping)/ Not
  - Ability to handle multiple operations
    - Consecutive / Simultaneous (reduced passages) / Not

- Ability to operate in different field conditions
- Maintenance needs
  - Complexity, downtime, life expectancy
- Ease of operation/ need for skilled labor (how technical intensive is the machine)

There are 10 main parameters, but some of them have specific subsets. For these cases, the punctuation is the average of the subsets. For example, to evaluate "precision in application", depending on the machine, could have points on both "seed deposition" and "improved nutrient management". If this were the case, the punctuation for "precision in application" would be the average.

Session 4) Breakout session: Examples

In this last session, participants placed a couple of examples of farm machinery to try to evaluate them using the parameters identified previously.

Example 1: In Bangladesh it is widely used the backpack sprayer. In this example, participants decided to use the index to evaluate a boom sprayer pushcart.

Example 2: For Morocco, participants decided to evaluate a Multi-Crop No-till Ferti-Cumseeder for a 4WT. This was compared to a conventional wheat seeder for a 4WT.

Example 3: For India, participants decided to evaluate the Happy Seeder for a 4WT compared to a conventional wheat seeder for a 4WT.

In the Appendix 1 is shown the table with the results. The total points of each example would be the percentage of climate-smart machines would be compared with the conventional. For example, the incorporation of the boom sprayer push-cart would mean a 21% improvement towards a climate-smart focus.

NEXT STEPS

- Q: How to evaluate certain production systems plus their mechanization system in different regions?
- Continue exploring and improving the proposed tool or index for measuring the level of "climate-smartness" compared with more conventional field operations
- Work on a manuscript for a first definition of "Climate-smart machinery"

Appendix 1. Results for session 4 "Breakout session: Examples"

	Boom sprayer push cart	Multi-crop No-till Ferti-Cumseeder 4WT	Happy seeder, wheat planter 4WT
1) Address challenges of climate change			
Time Responsive	6	7.5	8
Labor sensitive	7	2.5	2.5
Precision in application	4	2.35	2
o Seed deposition			
o Water-saving capacity		1.7	2
o Improved nutrient management		3	
o Other inputs			
Reducing losses	2	0	2
o Pre-harvest			
o During harvest			
o Post-harvest			
Land management	0	0	0
o Soil preparation			
o Topography			
2) Mitigation of climate change			
Plant environment	0	3.25	2.75
o Microbiological health		2	2
o Soil water holding capacity		2	2
o Soil organic matter (for carbon sequestration)		5	5
o Compaction (does it add to soil compaction?)		4	2
Reduced GHG emissions	0	3.7	4.5
o Improved fuel efficiency (reduced fossil fuel use)		2	1
o Renewable energy sources (electric/solar)		0	0
o Residue management (burning vs. non-burning)		5	8
o Helps to reduce fertilizer volatilization		4	0
Bolstering resilience			
Versatility	2	4	3.7
o Ability to handle different crops		5	5
Consecutive (crop diver) / Simultaneous (intercropping)/ Not			
o Ability to handle multiple operations		5	5
Consecutive / Simultaneous (reduced passages) / Not			
o Ability to operate in different field conditions		2	1
Maintenance needs	-1	-2	-3
o Complexity, downtime, life expectancy			
Ease of operation/ need for skilled labor (how technical intensive is the machine)	1	-3	-3
Total	**21**	**18.3**	**17.4**

Participant´s List. September 12th 2013

	Name	Institution	Duty Station	Signature
1	Jelle Filip Van Loon	CIMMYT	Mexico	[signature]
2	Owen Duncan Calvert	CIMMYT	Bangladesh	[signature]
3	Leon Rafael Jaman	CIMMYT	Zimbabwe	[signature]
4	Senthilkumar Kalimuthu	AfricaRice	Madagascar	[signature]
5	Mina Kumari Devkota Wasti	ICARDA	Morocco	[signature]
6	Joshua Esau Patiño Espejel	CIMMYT	Mexico	[signature]
7	Rabé Yahaya	IRRI	INDIA	[signature]

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5	Mina Kumari Devkota Wasti	ICARDA	Morocco	[signature]
6	Joshua Esau Patiño Espejel	CIMMYT	Mexico	[signature]
7	Rabé Yahaya	IRRI	INDIA	[signature]