A lightweight Raised Bed Machine (RBM) to raise seedbeds for higher farm income

An exploratory assessment of the Scaling Readiness of a mechanical measure to improve the livelihoods of farmers in irrigated drylands. An innovation of the International Centre of Agricultural Research in Dry Areas (ICARDA).
This assessment is carried by the Monitoring, Evaluation and Learning team (MEL) of ICARDA.

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Innovation at a glance

A lightweight Raised Bed Machine (RBM) to raise seedbeds for higher farm income

Egypt

Context

- Irrigated Dryland Agriculture
- Semi arid climate
- <250 mm annual precipitation
- Slopes less than 5%

The Targets

1 NO POVERTY

2 ZERO HUNGER

13 CLIMATE ACTION

17 PARTNERSHIPS FOR THE GOALS

Working principle

1. The field is prepared by two-way ploughing
2. The Raised Bed Machine raises seedbed while sowing seeds

Advantages and Disadvantages

PROS

- ✓ Higher efficiency for water and fertilizer use
- ✓ Increased farm income
- ✓ Local manufactory
- ✓ Reduced workload

CONS

- Investment costs for farmers
- Compaction on clay soils
- Limited availability

Partners

Tanta Motors ABOU FREIKHA 1950

ARC Agricultural Research Center

ICARDA Science for resilient livelihoods in dry areas

Background:

Source: WOCAT

The Raised Bed Machine (RBM)-innovation improves Egyptian wheat farmers' livelihoods by significantly reducing costs (30% less water, 20-40% less nitrogen fertilizer) and enhancing wheat yields (20-30% higher). The RBM technology helps to do more with less.
The innovation has been applied by the International Centre of Agriculture Research in Dryland Areas (ICARDA) and national partners in Egypt. Egypt is highly dependent on the import of wheat which accounts for 50% of the total national wheat demand. At the same time, Egypt is a water-scarce country with annual precipitation of less than 250mm and where 95% of its water comes from beyond its borders through the river Nile. This implies that most farming is irrigated. However, available irrigation water per farmer is rather low due to population growth. And due to clay soil and the use of flood irrigation, water logging and uneven water distribution over the field lead to soil salinization, harming the farmer's yields, exacerbated by the lack of water, insufficient use of fertilizers, and the use of relatively low-quality seeds. In particular, fertilizers are expensive leading to their insufficient and poor application. For these reasons, most people working in the agricultural sector live in poverty.
In effect, the objective of RBM is to fit within this context an intervention that realizes higher output with less input, consequently improving farmer livelihoods. Indeed, RBM improves farmers' resilience with increased water and nutrient efficiency through the benefits and positive effects of a decreased workload, increased yields, and more efficient use of resources (water, fertilizer and seeds), which translate to improved livelihoods.


FIGURE 1. (LEFT) THE RBM MACHINE IN ACTION. (RIGHT) WATER IN THE RAISED SEEDBEDS

The first stage of researching and designing the RBM technology was done in 2003. Introductions and pilots of the technology were designed together with regular farmers in the Nile Delta-area, from 2010 until 2013. In 2015, RBM technology was proven beneficial, permitting out-scaling. Thanks to the shown potential of RBM technology and Egypt's reliance on foreign countries for water and wheat, this technology has become a strong component of Egypt's national wheat campaign. The Egyptian Government aims to cultivate 2 million acres of wheat under RBM by 2022.

The technology has significant positive impacts on local farmers as applied water is saved by 25%, water pumping costs decreased by 25%, seed rate reduced by 50%, farming costs decreased by 30%, fertilizer use efficiency increased by 30%, and crop yield increased by 15–30% compared to conventional farming. Overall, it is estimated that farming under RBM is about 1/3 of the cost compared to conventional farming. Manually raising seedbeds was considered too expensive due to the required amount of labor. Thus, regular flood irrigation was practiced. Practically, this results in full surface flooding of the field. This has significantly higher evaporation hence increasing salinization, as opposed to furrow irrigation through raised seedbeds. Also, because water is well distributed over the field due to the furrows (reducing water stress and waterlogging), there is less leaching of the nutrient hence increased nutrient-efficiency. In case of over-irrigation, the raised seedbeds allow excess water to safely run-off. These features of better water disposal and reduced evaporation make RBM-technology well suited in the context of climate change characterized by more concentrated rainfall events and increased temperature hence increased evaporation. In addition, as RBM prevents waterlogging, it prevents land degradation (e.g. salinization).

Therefore, the livelihoods of farmers who have adopted this technology have been greatly improved. Farmers who have adopted RBM agree that RBM is affordable, easy to apply, improves production and is cost-saving. Furthermore, since this technology increases irrigation efficiency, it can mitigate existing upstream-downstream issues in terms of availability, as there is more available irrigation water. Also, as RBM technology is currently out scaled, it creates employment opportunities since RBM machines can be locally produced.

Technical Specification

The field is first prepared by two-way ploughing to make the soil sufficiently loose for the practice of RBM. The field should have a slope of less than 5% for the successful implementation of the RBM. Secondly, the raised bed seeder is pulled by a tractor and raises the seedbed while seeding wheat, hence the term Mechanized Raised Seedbed technology. In Figure 2, the width of the furrow (A) is 35–45 cm, as affected by the related soil texture. The width of the raised seedbed (B) is 100-130 cm, also dependent on the soil texture. Between seed rows (C) there is a space of 14 cm. This inter-row spacing of the crops relates to the type of crop seeded. The furrow has a depth (D) of 35-45 cm. However, after the first irrigation event, the depth could be reduced to 25 cm, due to the influx of loose soil. This is not a problem for the current growing season. This technical drawing is based on the most common conditions where RBM is implemented. These are that the crop is winter wheat, the soil texture is mostly clay and the system is watered through irrigation coming from the Nile River. If RBM is used under different circumstances, the dimension would change as well.

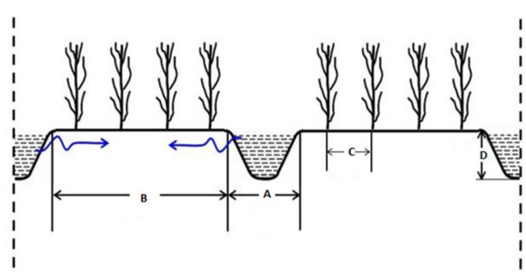


FIGURE 2: TECHNICAL DRAWING OF THE RAISED SEEDBEDS

Scaling Readiness and its Concepts

Scaling Readiness (SR) is a conceptual approach used to improve the scalability of an innovation package within a specific context by guiding users in identifying the barriers to scaling i.e., bottlenecks. It is a dynamic process where innovation packages, bottlenecks and SR scores change over time and place as a result of changing contexts or innovations. This exploratory SR assessment includes two steps. The first is to characterize the innovation, and the second is to diagnose the components of the innovation.

This section aims to briefly describe the concepts and logic used in SR. In the subsequent section, the innovation is characterized and diagnosed, i.e., the SR concepts applied.

Characterization

Characterizing an innovation consists of defining the innovation, the target of its scaling, the novel components (aka., complementary innovations), and the innovation package. This relates to the following concepts:

- The Core Innovation: the innovation to be scaled. This is context-independent, hence more general, and broadly formulated.
- The Target: where to scale, for whom, and for what (SDGs)
- The Complementary Innovations: co- (or sub-) innovations that are indispensable for the successful scaling of the core innovation. These are context-specific and can be viewed as the enabling environment.
- The Innovation Package: a comprehensive statement of the interaction between core and complementary innovations, featuring the context (country + subnational level), the target beneficiaries, and targeted SDGs.

➢ Complementary innovations can be of different types. They are distinguished as:

  - Feature: a modification of something, e.g., cash crops to a cropping system, lightweight tractors, etc.
  - Tool: a thing used to support a process, e.g., machinery, phone app, etc.
  - Product: a thing that is used, e.g., seeds, fuel, seedlings, etc.
  - Principle: a change in belief, behavior, or assumptions (something intangible), e.g., gender equality, farmer perception.
  - (Institutional) Arrangement: an arrangement between entities, e.g., strategy, cooperatives, contracts, meetings etc.
  - Service: a service provided to stakeholders e.g., capacity development, loan systems/ micro-financing, extension, agricultural mechanization hiring, etc.
  - Technique: how to do something, e.g., rainwater harvesting or raised seedbeds.

➢ Complementary innovations are often related to one or more of the eight enabling aspects:

  1. Awareness: to make relevant people aware of the innovation, e.g., a radio broadcast

2. Funding: to have sufficient funding for research or use improvements e.g., a proposal framework or stakeholder collaboration
3. Availability: to have sufficient supply to meet demand e.g., enough seedlings
4. Accessibility: to make the innovation accessible for users e.g., a phone number or contact person
5. Affordability: to make the innovation affordable, e.g., subsidies, loans, or cheaper designs
6. Simplification: to simplify the science complexity so it is understood e.g., a simple grazing calendar rather than formulas for grazing capacity.
7. User Friendliness: to make the innovation user friendly e.g., a plough that is suitable for the commonly used tractors.
8. Benefits for targeted group: innovation to improve the benefits e.g., seedlings that provide more fodder

Diagnosing

The complementary innovations are diagnosed so that the bottleneck hindering scalability is revealed. Diagnosing consists of calculating the Scaling Readiness Score – the product of multiplying the *Innovation Readiness Score* and the *Innovation Use Score*. These two concepts are defined and scored as follows:

Innovation Use is a metric used to assess the extent to which an innovation is already being used, by which type of users and under which conditions, with a scale ranging from no use (lowest level – 0) to common use (highest level – 9). (source: MELCOP/ PRMF Glossary).

Innovation Readiness is a metric used to assess the maturity of an innovation (its preparedness for scaling) with a scale ranging from the idea (lowest level – 0) to validated under uncontrolled conditions (highest level – 9). (source: MELCOP/ PRMF Glossary).

Table 1: Left: Description per Innovation Use level; Right: Description of Innovation Readiness levels

Use Levels	Generic level label	Generic level description
9	End-users/ beneficiaries (common)	The innovation is commonly used by end-users or beneficiaries who were not involved in the initial innovation development
8	End-users/ beneficiaries (rare)	The innovation is used by some end-users or beneficiaries who were not involved in the initial innovation development
7	Unconnected next-user (common)	The innovation is commonly used by organizations not connected to partners involved in the initial innovation development
6	Unconnected next-user (rare)	The innovation is used by organizations not connected to partners involved in the initial innovation development
5	Connected next-user (common)	The innovation is commonly used by organizations connected to partners involved in the initial innovation development
4	Connected next-user (rare)	The innovation is used by some organizations connected to partners involved in the initial innovation development
3	Partners (common)	The innovation is commonly used by partners involved in the initial innovation development
2	Partners (rare)	The innovation is used by some partners involved in the initial innovation development
1	Project lead	The innovation is used by the organization(s) leading the innovation development
0	No use	The innovation is not used

Readiness Levels	Generic level label	Generic level description
9	Proven innovation	The innovation is validated for its ability to achieve a specific impact under uncontrolled conditions
8	Uncontrolled testing	The innovation is being tested for its ability to achieve a specific impact under uncontrolled conditions
7	Prototype	The innovation is validated for its ability to achieve a specific impact under semi-controlled conditions
6	Semi-controlled testing	The innovation is being tested for its ability to achieve a specific impact under semi-controlled conditions
5	Model/ early prototype	The innovation is validated for its ability to achieve a specific impact under fully-controlled conditions
4	Controlled testing	The innovation is being tested for its ability to achieve a specific impact under fully-controlled conditions
3	Proof of concept	The innovation's key concepts have been validated for their ability to achieve a specific impact
2	Formulation	The innovation's key concepts are being formulated or designed
1	Basic research	The innovation's basic principles are being researched for their ability to achieve a specific impact
0	Idea	The innovation is at idea stage

The complementary innovation (sub-innovation) that is scored with the lowest Scaling Readiness Score is considered the bottleneck i.e., the one that prevents the innovation package from scaling. This logic is based on Liebig's law of the Minimum. This is illustrated in Figure 3 (Sartas, et al., 2020).

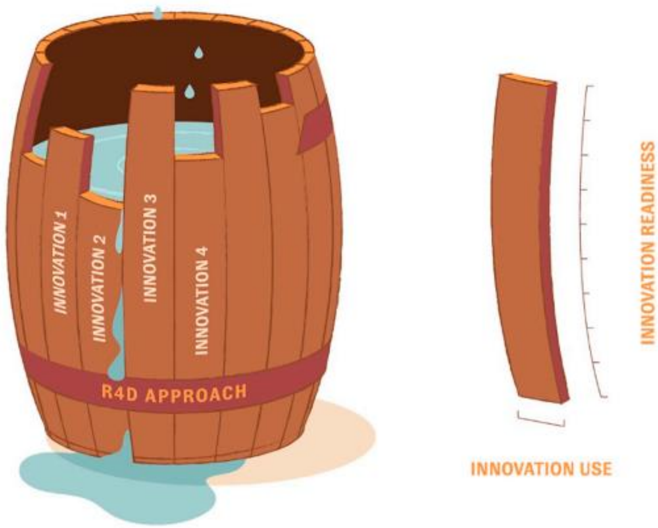


FIGURE 3: LIEBIG'S BARREL ANALOGY OF THE LAW OF THE MINIMUM DEPICTED HERE IN THE CONTEXT OF SCALING READINESS

Only experts who understand both the innovation and the scaling context are qualified enough to score the core and complementary innovations for their innovation readiness and innovation use (i.e., to serve as an informant). While rating an innovation, it is important to include references with the highest quality (e.g., scientific papers), else other reputable references (e.g., blogs). This is essential to support their scoring and base the Scaling Readiness on.

Scaling Readiness Assessment of the Innovation

Characterizing

Target:

To improve farm income and resource efficiency of smallholder farming in irrigated drylands by combining mechanical plantation with raised bed preparation by lightweight machines

Core innovation:

Mechanically raised seed bedding by lightweight machines.

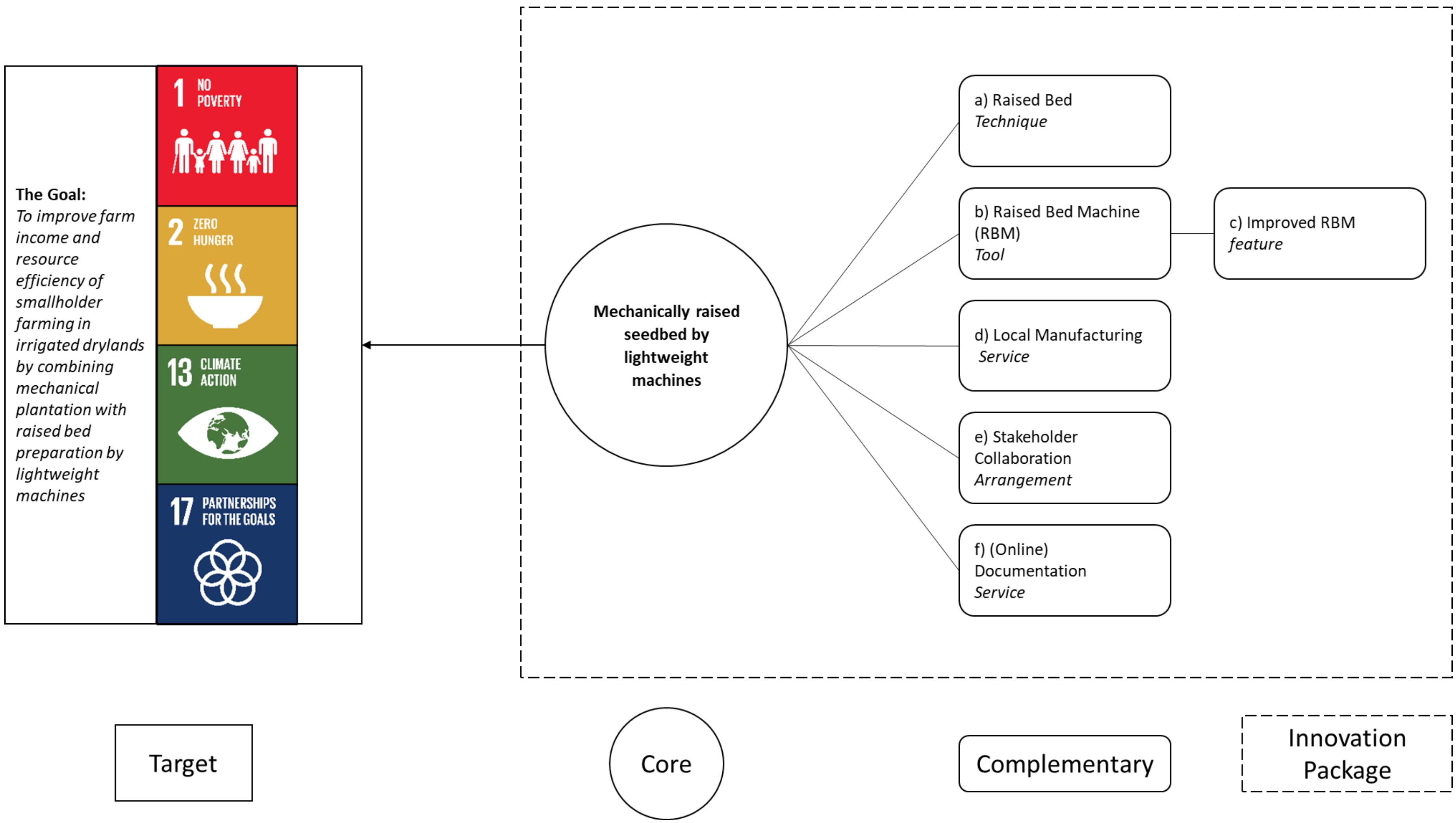
Complementary innovations:

a) Raised Bed – the technique of raising seed beds (Figure 2)
b) Raised Bed Machine - The machine that is attached to a tractor that simultaneously raises the seedbed, creates irrigation furrows, and disseminates seeds onto seedbeds (Background:
Source: WOCAT section).
c) Improved RBM – a feature of the current Raised Bed Machine to improve the machine's effectiveness and improve the benefits for its users as to increase the number of end users and beneficiaries, given the local context of Egypt's heavy clay soils in the Nile Valley and Nile Delta. The main improvement consists of lightening the current weight of RBM from more than one ton to about a half ton. The rationale is that heavy machines lead to soil compaction which adversely affects soil physical, chemical, and biological properties. As a result, crop yields decrease, time, cost and fuel requirements for tillage operations increase, soil aeration is hampered, denitrification increases, aerobic microbial processes are impaired, and net income decreases (Hakansson, 2005; Keller et al., 2019; Parvin et al., 2021). The current heavy RBM requires a tractor with 90 hp which is not common in Egypt. Small tractors with 35-40 hp, that can be used for pulling, have been commonly used for most agronomic practices such as tillage and land levelling. The new light machine would reduce the required amount of energy for the pulling tractor. The lightweight machine is designed, and the first prototypes will be manufactured soon.
d) Local manufactories – a service provided by the local manufacturers to make the raised seedbed machine available and accessible for farmers. It also enhances local employment.
e) Stakeholder collaboration framework – a commonly agreed upon strategy between collaborators and funders within the private, academic, and public sectors.
f) (online) Documentation – documents to share the knowledge of the innovation to a wider audience making them aware and making the innovation accessible.

The innovation package:

Joint mechanical seeding and raised bed preparation using lightweight machinery in smallholder furrow-irrigated dryland farming to enhance farm income and resource-use efficiency.

To improve the farm income and resource efficiency by combining mechanical plantation and raised bed preparation with light weight machines for smallholder farming in irrigated drylands



Diagnosing

The following tables show the complementary innovations, the rationale for their use and readiness within the context of the innovation package, their scoring and the evidence that supports their scoring.

Innovation Use

Complementary innovation	Type	Rationale	Sources	Use Score
a) Raised Seedbeds	Technique	This technique is a well-established universal practice and is commonly used by farmers in Egypt's Nile Valley and Delta and is independent of project interventions in Egypt. However, uptake is not widespread because its manual implementation is laborious. Although automation helps to utilize the technically installed performance and reduce labours, it has not been able to stop the trend toward further growth in size.	1,2,3,4	8
b) Raised Bed Machine (RBM)	Tool	The machine has been used by many farmers led by organizations not involved in the initial innovation. Tractors pulling the machines should be of 90 hp, which is not common among farmers.	1, 2, 3,	7
c) Improved RBM	Feature	Few similar lightweight machines have been introduced by the Agricultural Engineering Research Institute at ARC for research in Egypt. The lightweight version of the RBM has been designed, and the first prototypes will be manufactured soon. One example of lightweight machinery developed by the ARC is a relatively light seed drill designed and manufactured by AEnRI/MARL engineers which can be towed by tractor of medium power (60-80 HP). A demonstration of this mechanical seed drill has been conducted for the season of wheat 2019/2020 in Fayoum and Menia governorates to disseminate the new	7	3

		machine. At the end of the season in Minya 276.21 feddan were planted with mechanical seed drills; and in Fayoum 340.5 feddan were planted by mechanical seed, for a total of 616.71 feddan.		
d) Local Manufacturing	Service	Some partners including the Agricultural Engineering Research Institute at ARC have been relying on some local manufactories for the maintenance and replacement of existing machinery components.		4
e) Stakeholder Collaboration Framework	Arrangement	No agreed Stakeholder Collaboration Framework exists that can bridge the gap between innovative research and practicality on the ground. Farmers prefer old machinery for its simplicity and applicability, while the latest innovations are not preferred.		0
f) (online) Documentation	Product	Documentation of projects is performed for many other innovations. However, their usefulness to inform end-users is limited.	5,6	8

Innovation Readiness

Complementary innovation	Type	Rationale	Sources	Readiness Score
a) Raised Seedbeds	Technique	This technique is well-validated globally for its ability to conserve resources and achieve higher yields, independent of project interventions.	4, 5	8
b) Raised Bed Machine (RBM)	Tool	RBMs have proven to reduce the workload involved in constructing seedbeds but still face some problems with their weight which leads to soil compaction, thereby adversely affecting soil, physical, chemical, and biological properties.	1,2,3,7,8	6
c) Improved RBM	Feature	A relatively light machine has been designed, manufactured, and tested in 616.71 feddan by AEnRI/MARL engineers. The machine can be towed by tractor of medium power (from 60 to 80 HP instead of 90 HP). Pilot machines have been tested on the research scale and proved their effectiveness. Capitalizing on these findings, new designs of lighter machines with about 0.5 ton have been introduced by AEnRI in Egypt and the General Commission of Scientific Agriculture Research (GCSAR) in Syria. The first prototypes will be manufactured soon.	9	3
d) Local Manufacturing	Service	The local workshops can manufacture a completely new light RBM, with guidance and technical supervision in the initial phase until the concept is proven. Similar light-weight machineries have been recently manufactured in Syria and Egypt for research purposes, but no published reports or literature exist because of the newness of this approach in both countries. Currently, a new design for a pilot lightweight RBM has been		1

		agreed upon and is under manufacturing. Documentation of this process will be considered as first of its kind in both countries.		
e) Stakeholder Collaboration Framework	Arrangement	This is a basic idea based on the initial support of all stakeholders including research, policy, extension institutions as well as farmer associations.		0
f) (online) Documentation	Product	It has proven to be useful for decision-making but done within simulated projects. It is not used widely in this project.	6	7

Scaling Readiness Scores

As a result of the diagnosis, the Scaling Readiness scores can be assessed by multiplying the innovation use score by the innovations readiness score. The **Error! Reference source not found.** and Figure 4 Figure 4. Plotting the complementary innovation scores in relation to one anotherprovide an overview of the scores.

TABLE 2. SCALING READINESS SCORES OF THE COMPLEMENTARY INNOVATIONS

Complementary Innovation	Scaling Readiness
a) Raised Seedbeds	64
b) Raised Bed Machine (RBM)	42
c) Improved RBM	9
d) Local Manufacturing	4
e) Stakeholder Collaboration Framework	0
f) (online) Documentation	56
Average	29

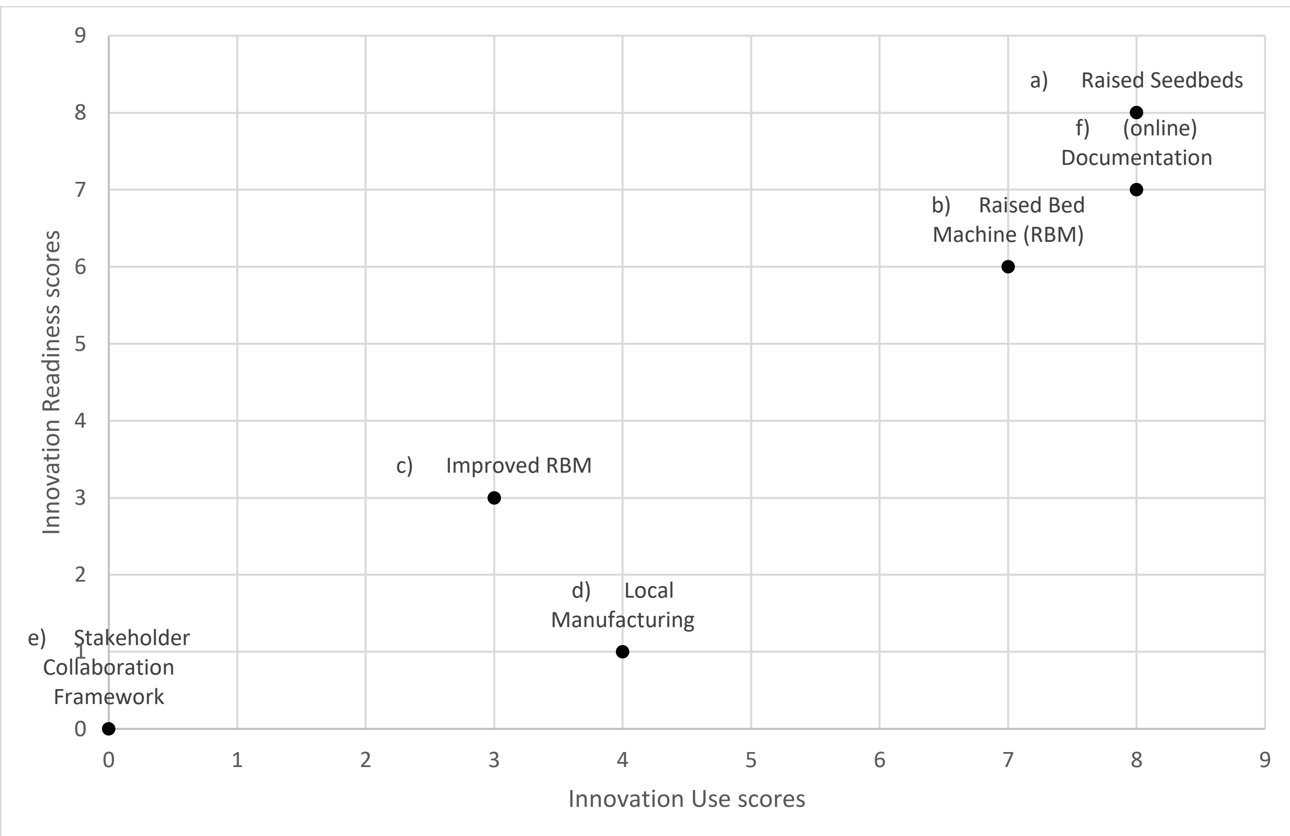


FIGURE 4. PLOTTING THE COMPLEMENTARY INNOVATION SCORES IN RELATION TO ONE ANOTHER

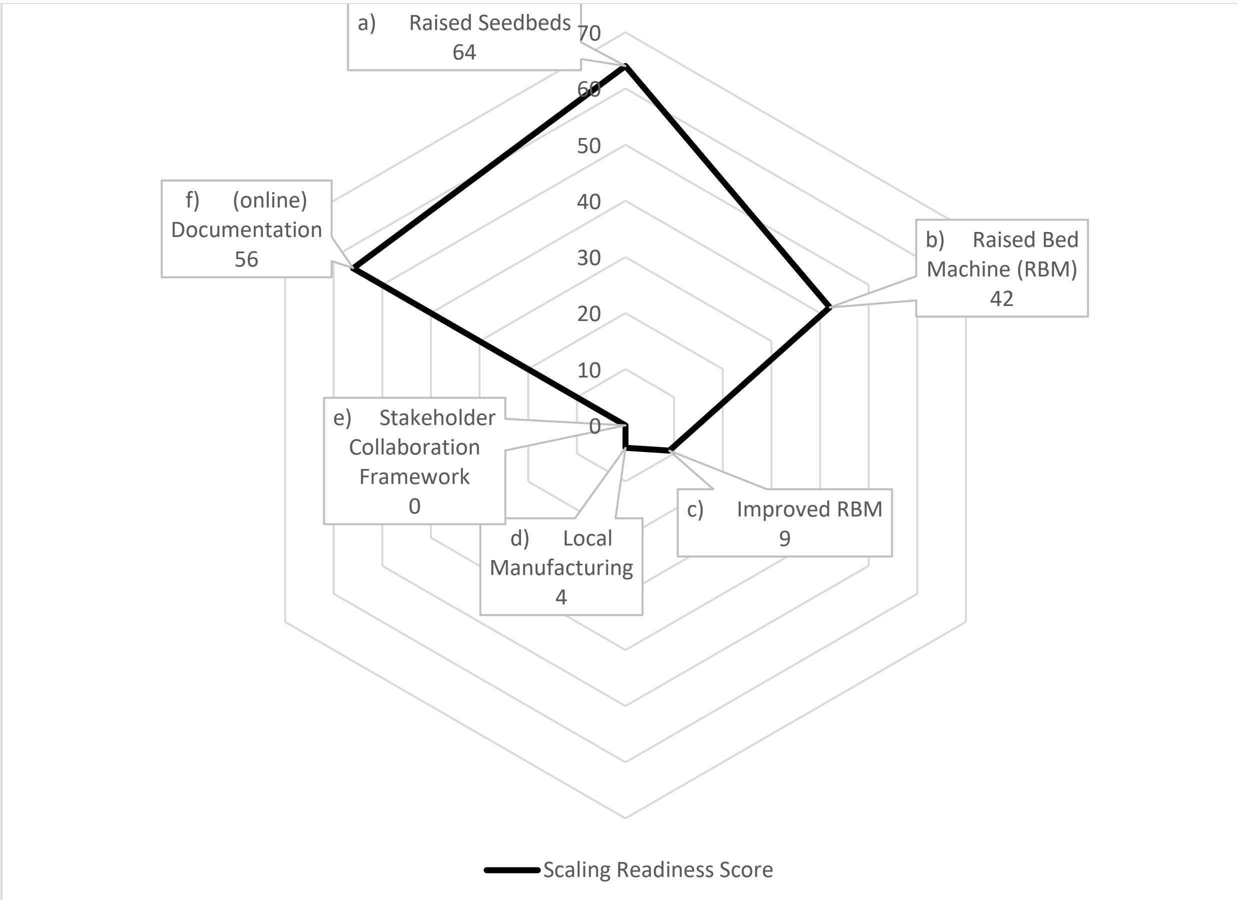


FIGURE 5: SCALING READINESS SCORE PLOTTED IN RADAR GRAPH AND PRESENTED IN A TABLE

Discussion and Recommendations

In this exploratory assessment, only one informant for the innovation was used, while the Scaling Readiness assessment approach advocates the use of a diverse team of informants. This broadens the scope and improves the inclusion of additional complementary innovations, which is why it is advisable not to limit the assessment to the expertise of one informant. In addition, a single characterization and diagnosis of an innovation is a snapshot of the innovation at a specific time and context and is subjected to the informant's own biases. SR assessment is a dynamic process hence the characterization and diagnosis may change at a later time or different place. Despite that, useful observations and recommendations can be made from this exploratory assessment:

- The technical and conventional aspects of the innovation (the use of raised beds and the regular RBM machine) were shown to function well and have reached a high Scaling Readiness score.
- The lightweight feature to improve the RBM can be studied and improved further to reach a higher Innovation Readiness score and thereby win legitimacy.
- The bottleneck for this innovation package is the (currently non-existing) stakeholder framework that aims at scaling. If stakeholders such as the local manufacturers, government, and farmer organizations are aligned, together they can catalyze the scaling. The high SR scores of the raised seedbed technique and the non-lightweight RBM show that innovation is indeed working and used in a semi-to un-controlled environment, indicating the legitimacy of the innovation package for other stakeholders to collaborate on. Funding originating from such collaborations can be used to do further research into the lightweight feature of the RBM and promote further research and development to locally manufacture the machines. By including farmer organizations or national agricultural research centers (ARC), the innovation can become more accessible to farmers.
- Based on the eight enabling aspects, it would be wise to invest in collaborations or complementary innovations that improve funding, availability, affordability, and accessibility of the package, such as local manufacturing and stakeholder collaboration.

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