Science for resilient livelihoods in dry areas

Adoption and Economic Assessment of Improved Technologies in ICARDA's Arabian Peninsula Regional Program

Boubaker Dhehibi[1]; Arash Nejatian[1,2] and Azaiez Ouled Belgacem[1,2]

1. Research Program on Resilient Agricultural Livelihood Systems (RALS), International Center for Agricultural Research in Dry Areas (ICARDA), Amman, Jordan.
2. Arabian Peninsula Regional Program, International Center for Agricultural Research in Dry Areas (ICARDA), Ajman, UAE.

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Dalia Building, Second Floor, Bashir El Kasser St, Verdun, Beirut, Lebanon 1108-2010.
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List of acronyms

ADOPT	Adoption and Diffusion Outcome Prediction Tool
AP	Arabian Peninsula
APRP	Arabian Peninsula Regional Program
CBA	Cost Benfit Analysis
CBR	Cost Benefit Ratio
CGH	Cooling Green House
FGD	Focus Groups Discussion
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
ICARDA	International Center for Agricultural Research in the Dry Areas
IF	Irrigated Forages
IPPM	Integrated Production and Protection Management
IFAD	International Fund for Agricultural Development
IRR	Internal Rate of Return
KSA	Kingdom of Saudi Arabia
PBA	Partial Budget Analysis
R&E	Research and Extension
RR	Rangeland Rehabilitation
SC	Spinelless Cactus
SPS	Soilless Production System
UAE	The United Arab Emirates

Key messages

Executive summary

The objective of this report is threefold. Firstly, the report is to investigate costs and benefits associated with ICARDA-APRP technologies adopted by Arabian Peninsula (AP) farmers and identify the most effective and economic indicators based on general information and responses of AP countries farmers and the cost benefit analysis framework.

Secondly – based on the fact that there is much existing knowledge about the factors that influence adoption of new technologies and practices in agriculture – few attempts have been made to construct predictive quantitative models of adoption for use by those planning agricultural research, development, extension services and policy-making. It is within this framework that the sub-objective purpose is to estimate the expected rate of adoption of these innovations and identify main constraints that limit the adoption process in the AP region through using ADOPT (Adoption and Diffusion Outcome Prediction Tool). The application of ADOPT is the result of the attempt to construct predictive quantitative models of adoption, by providing predictions of the improved AP practice's likely rate and peak level of adoption, as well as estimating the importance of various factors influencing adoption. ADOPT employs a conceptual framework that incorporates a range of variables, including variables related to economics, risk, environmental outcomes, farmer networks, farm and farmer characteristics and finally, the ease and convenience of the new practice. A focus group discussion (FGD) methodology was used to apply ADOPT to a panel of farmers in each country and for each introduced technology. In the FGD's we streamlined 22 discussion questions around four categories of influences on adoption: characteristics of the innovation, characteristics of the target population, the relative advantage of using the innovation, and learning of the relative benefit of the change.

The third and final objective was to assess the AP researchers and extension agents' perceptions of technology-specific attributes and characteristics. The omission of researcher and extensionist's evaluation of technology-specific attributes may bias the results of factors conditioning adoption choices, so a Likert-type scale was used using a sample of seven Research and Extension (R&E) centers in the AP region.

Empirical findings indicate clear evidence on the economic profitability of the evaluated technologies (native forages, integrated production, protection management, etc.). The results of the cost benefit analysis (CBA) for the technologies implemented in Yemen case revealed a clear profitability of the improved forage named clitoria (perennial legume forage) in comparison to the sorghum (seasonal grass forage). On average, the adoption of clitoria, a protein-rich forage, implies a reduction of about 39% in total cost when it is compared with sorghum and an increase of about 207% and 479% on revenue and net return, respectively. These findings are confirmed by the high benefit cost ratio (BCR) when adopting clitoria (7.97) in comparison to farming sorghum (1.86). In addition to reducing the total costs and increasing the total revenue, the major perceptible benefit is the amount of water saved when adopting this technology, which contributes to a reduction of about 48% per hectare.

Moreover, the economic valuation between the local variety of buffelgrass (*Cenchrus ciliaris*) locally called libid and an introduced variety called gayanda reveals a high BCR among farmers who adopted gayanda (around 22.32) against farmers who practicing local libid forage (18.35). Findings indicate although we noted a slight increase in the total costs for the adopters of such technology, the net return is increasing greatly by about 126%. The major benefit on adopting this technology is the high level of revenue due to the increase in yield. Therefore, the tangible benefit from this technology is the high amount of forage produced per hectare multiplied by its unit price during the period of analysis.

The third technology evaluated was the Soilless Production System (SPS – i.e. hydroponics) against the soil production system in protected agriculture. This technology was introduced to the farmers with the purpose to enhance the sustainability of their farming systems through an efficient use of resources, mainly water. The empirical findings indicate that the BCR for the adopters of this technology for the cucumber crop is an average of 2.91, whereas this ratio is almost 1.4 for the farmers keeping the soil production system. The tangible benefit from the adoption of this technology is, in addition to the high level of productivity and production, the amount of conserved water (around

200% saving in comparison with the soil production system). By applying this technology, the net return per hectare is increased by around 260%.

The interventions introduced by the project using integrated production and pest management (IPPM) were also subjected to economic analysis using partial budgeting analysis by comparing the adoption of the IPPM package with the common practices of chemical pesticides or no pest control. The analysis showed that using IPPM increased yields by 15% per hectare compared to yields with chemical pest control and gave a reduction per hectare in total costs of about 11%. Economic analysis showed that the net benefit to cucumber growers by applying IPPM technology was US$1,903. The financial indicators such as BCR was around 1.72 among farmers who practiced the IPPM against 1.53 among farmers who did not practice it.

The economic valuation of the ICARDA-APRP improved technologies highlighted the following:

- There is clear evidence of the economic profitability (reducing production costs and increasing net returns) if these improved technologies are applied appropriately.
- The adoption of such technologies offers an opportunity for arresting and reversing the downward spiral of resource degradation, protecting the environment (e.g., less chemical use), decreasing cultivation costs and making agriculture more resource-efficient (e.g., irrigated water) and sustainable for the cucumber growers in Yemen.
- A sustainable increase in productivity of crops and forages can be achieved, if the environment is better protected and an important quantity of water can be saved if farmers/growers are encouraged to adopt the improved technology packages.
- The benefits of those technologies must be clearly perceived by farmers given their own socio-economic conditions.

The results from the ADOPT exercise confirm the extent to which tool has a potentially important role in providing information on the likely rate and peak level of adoption as well as estimating the importance of various factors influencing adoption for the improved technologies implemented by the ICARDA-APRP project. This includes provision of information for those investing in agricultural research and development and building knowledge of the adoption process among those engaged in projects that are intended to result in changed farming practices in the AP region.

The quantitative predictions about the adoption outcomes for the APRP-improved farming practices showed that predicted peak of adoption and time to reach it vary between technologies, countries, as well as within the same countries.
The results from the FGDs with farmers in Bahrain, KSA, Qatar and Yemen – with respect to the adoption of SPS – showed that the peak adoption rate for this technology is predicted to be 95%, 91%, 8% and 86% after a period of 17.5, 18.3, 19.2 and 18.5 years, respectively. In Oman, the findings reveal a slight difference between the regions on the predicted levels in SPSs. This difference is mainly due to the socio-demographic and economic conditions of the growers, on top of the farming system practiced in each region.

According to factors affecting both the peak of adoption and the time to reach it, results from the sensitivity analysis indicate that trialability of the technology, in addition to its complexity where the effects of its use cannot be easily considered, the main factors constraining the widespread of such technology for the mentioned. Nevertheless, in Bahrain, the adoption of the soilless system is affected negatively by the fact that it is not observable by the farmers – who are yet to adopt it – when it is used in their area. In addition to the factors mentioned above, three factors are specific to the Yemeni growers that affect the considered technology: the risk; the investment cost; and, its profitability in the years that it is used. In Qatar, an additional factor is the need to develop substantial new skills and knowledge to use the innovation. This last factor also influences the time to hit peak level adoption of soilless systems in Oman (including the regional adoption).

The quantitative predictions of the IPPM technology peak adoption rate for Bahrain, KSA, and Yemen for this technology is predicted to be 95%, 94% and 85% after a period of 11.2, 21.6 and 13.8 years, respectively. After five years from the start, the predicted adoption level is quite acceptable for Bahrain and Qatar compared to KSA where this predicted level is very low. Furthermore, this level remains low after 10 years since the startup of the adoption process. This could be explained by the existence of many constraints which prohibit the adoption and affect mainly the time taken to peak adoption level. Such constraints could be summarized as follows: short-term financial constraints of the farmers, the trialability of the technology, its complexity, lack of an effective advisory service and a lack of know-how in the use of the IPPM technology.

The predictions of the improved irrigated forages practice's likely rate and peak level of adoption, as well as the estimated importance of various factors influencing its adoption, reveals a similarity in the years taken for peak adoption in KSA, Qatar and Yemen (for clitoria forage) where this peak (95%) is expected to be after 13.5, 14.6 and 13.2 years, respectively. In the case of Yemen, this peak is predicted for buffel grass to be after 17.3 years. In Oman, we note that this peak can be reached in a shorter time in comparison with the rest of AP countries. It is expected to be around five years for the northern region and between six and eight years for the southern region. This variability is because the natural environment of the northern region of Oman is characterized by important water and animal resources which enhance the adoption of this technology. With respect to the factors influencing the adoption process, we identified mainly four key drivers: characteristics or attributes of technology; financial factors; the change agent (extension system, professional, etc.); and, the socio-economic and physical environment in which the technology takes place.

We also tested the ability of ADOPT to predict adoption levels and factors affecting the adoption of SC technology, done only in Qatar. The likely adoption rate for the adoption of this technology is predicted to be 95% after a period of 9.4 years. The predicted adoption level in five and ten years from the starting period on the adoption of this technology is 80 and 90%, respectively. According to factors such as farmers' profit, environmental, and risk orientations, the number of farmers expected to benefit from the innovations, the environmental and profit advantages, the ease and convenience of implementation and use, and therefore the level of peak adoption for the innovations is quite high.

Finally, we predicted adoption levels and factors affecting the adoption of Rangeland Rehabilitation (RR) technology both in KSA and Qatar. The empirical findings for this technology indicate a huge difference between KSA and Qatar on the predicted peak of adoption of this technology. Although the predicted years to peak such adoption are around 18 years, the peak of adoption is expected to be 92% for KSA and 11% for Qatar. This predicted peak remains very low even during the first five and ten years for the case of Qatar. The sensitivity analysis suggests that many factors are contributing to constraining this peak level of adoption mainly for Qatar. These factors are the complexity of the innovation, its trialability, the need for farmers and communities to develop substantial new skills and knowledge to use the innovation. In addition, the problem linked to the up-front cost of the investment relative to the potential annual benefit from adopting this technology.

The quantitative predictions results provide a valuable alternative and comprehensive empirical basis for improving our understanding of individual users' acceptance of innovation and about the adoption outcomes for these new farming practices introduced by the project. Such results suggest the following:

- Although the complexity of some technologies (case of rangeland management system), there is a willingness from farmers and growers to adopt them.
- The predicted level for peak adoption of these technologies is different between the AP countries and even within the same country (case of Oman).
- The characteristics of the technology is a determinant on its level to peak adoption and on the time to peak the corresponding adoption level (low predicted level of adoption for the IF and high predicted level of adoption for the IPPM and rangeland rehabilitation).
- Technical assistance, substantial new skills and knowledge, up-front cost of investment, financial resources and effective extension advisory services are considered the main factors influencing the adoption of these technologies.
- The action on these factors will affect only the time to achieve peak adoption levels of the said technologies.
- Technology characteristics proved to be important for farmers' decision-making, which allow decision-makers and planners in R&E to determine and target the characteristics of new technologies, to lead to their easy transfer and diffusion among the AP small holding farmers.
- Farmers are encouraged to adopt these proven and promising technologies. In AP areas, increasing farmers' knowledge and perception of the merits of such technologies through better access to technical information, extension, and training will help them

to develop a positive economic and environmental assessment of the proven technologies

With respect to the third objective, the findings from the Likert-type scale show that assessments of researcher and extension agents' perceptions of the ICARDA-APRP technology-specific characteristics/attributes – technology needs skill; complexity; affordability; reduces farming costs; increases profits; reduces the risk in farming operations; environmental benefit; implementation of the technology is easy; easy to monitor, assess, and follow up; communicable; compatible; and finally, if the technology is divisible – are key factors on determining adoption and driving adoption decisions between the AP countries. The results show a clear convergence on the perception of researchers and extension agents among the AP countries regarding the soilless production, integrated protection and production pest management, as well as RR technologies. The analysis between countries suggest that, in Kuwait, the irrigated forages and SC technology assessments are getting a low score. This is an indicator that these technologies are not very well diffused and therefore an additional effort is needed to spread such technologies. The cooled greenhouse technology is ranked with a low score in Yemen. This could be explained by the fact that adoption of this innovation is very low as it is mainly constrained by the high level of up-front cost investment in this technology where it is not affordable by small-holder farmers.

In summary, there is a clear disparity at the regional scale of level of adoption and on the factors affecting and encouraging the adoption of a specified technology (i.e. case of SPS and irrigated forage in Oman and Yemen). Thus, scaling-up and widespread to other region within the same country could be facilitated with interactive similarity maps that identify similar socio-economic and environmental contexts. Hence, only technologies with a high financial feasibility should be promoted and therefore farmers should be encouraged to join established and strengthened associations, through which training and technical assistance with access to extension information can be provided. The policy implication that emerges from this finding is that action can only be achieved through planned and designed programs in partnership with all concerned organizations and targeting the appropriate beneficiaries.

Having this information and knowing which technology characteristics proved to be important for farmers decision-making will certainly allow managers and planners in R&E to determine and target those characteristics of new technologies that lead to their easy transfer and diffusion among the AP small-holder farmers.

Key words

Adoption-diffusion, constraints, economic evaluation, technology characteristics, perceptions, decision-making, APRP technologies.

Highlights

- We evaluated the economic profitability of the improved technologies implemented in the frame of the ICARDA-AP regional program.
- We estimated the expected adoption level and time to peak at the maximum level of adoption of these improved technologies.
- We identified the main constraints affecting the adoption level and the spread for each of the implemented innovations.
- We assessed the AP researchers and extension agents' perceptions of technology-specific characteristics and attributes, significantly condition technology adoption decisions.
- We provided key practical recommendations to ensure the successful adoption-diffusion and widespread transfer of these technologies.

1. Introduction

1.1. Background

The aridity that prevails in most of the Arab countries means that the AP is the poorest in the world in terms of water resources, both globally and per inhabitant. Arid conditions in these countries act as a natural constraint for expansive agriculture. Only 1.7% of the total land area within the Gulf Cooperation Council (GCC) countries is arable. As a result, 60–80% of total food demand is currently met from external sources and the agriculture contributes only around 1-4% of the GCC countries' Gross Domestic Product (GDP) as compared to 10-20% for their emerging market counterparts. Moreover, rapidly growing populations and rising per capita consumption has become the key driver for growth in food consumption. Indeed, increasing income levels and rising prosperity are leading to a shift in food consumption patterns, with the demand for food products rising fast and contributing to more intensive land use.

The scarcity of arable land and water have limited the growth of AP agriculture. With the limited potential for the agriculture sector, optimizing use of these limited resources for technology transfer in agricultural development is one of the biggest challenges facing any decision-maker, including the end users and growers. Thus, developing a sustainable and improved agriculture system would have a significant impact on helping these countries to shift their agricultural priorities from self-sufficiency to food security.

The research for development program for the region known as Arabian Peninsula Regional Program (APRP) – implemented by the International Center of Agricultural Research in the Dry Areas (ICARDA) upon request from the AP-National Research Systems – is working since 1995, through developed and proven technologies, to improve the agriculture productivity and contribute to reducing the food production gap, as the AP region, already among the largest food importers, is set to witness a significant growth in import of food products in the coming years.

Several proven technologies and improved packages for the different production systems have proven their evidence at the research stations, such as irrigated forages, including SC, RR and protected agriculture and its associated techniques (SPSs plus Integrated Production and Protection Management (IPPM)). However, some of these technologies are not widely adopted; while developing improved technologies are important for farmers in the rural livelihoods for this region, new technologies can only affect livelihoods positively if they are profitable and then adopted by farmers.

It is in this perspective that this study is prepared within the framework of the ICARDA APRP program and in the frame of improving food security and sustainable natural resources management through enhancing integrated agricultural production systems within the AP project.

1.2. Purpose of the research

In the light of these challenges, and in order to enhance the adoption and accelerate its process and scaling up of these proven and promising technologies, the purpose of this study is threefold. The first purpose is to provide a comprehensive picture of the economic valuation (examination of the costs and benefits on using these technology trade-offs with respect to the conventional ones). Second, to evaluate their level of adoption from farmers' perspectives, with special emphasis on the main factors affecting and limiting the adoption of these technologies in the Arabian Peninsula. Third and lastly, to assess the basic criteria and the perception on the adoption of such technologies with the AP national R&E system with the finality to better understanding the existing farming systems and farming communities; quantify the number of technology users over time, to assess impacts or determine extension requirements; and, identify the main constraints (technical, socioeconomic, environmental, social, cultural, institutional, political, etc.) and work on sustainable solutions.

1.3. Objectives of the research

In line with the knowledge gaps above justification and with the purpose to enhance adoption, accelerate its process and scale up of these proven and promising technologies (RR, irrigated forages, SPS, plus integrated production and protection management systems), the specific objectives of this study are as follows:

- Analyze the on-site costs and benefits of adopting the identified ICARDA-APRP targeted technologies in the region on farms using partial budget analysis (PBA) method. In this research the CBA indicator was used as a decision tool after the computation of all cost and benefits were valued in local currency to obtain the Internal Rate of Return (IRR) and the Cost-Benefit Ratios (CBR) or net welfare.

- Estimate the expected rate of adoption of these technologies in the AP countries through using ADOPT software.
- Understand the perceptions of AP R&E systems on the impact of the ICARDA-APRP technologies characteristics on their adoption level, and consequently to identify the adoption barriers and constraints.
- Draw recommendations to promote adoption, ensure scaling-up and widespread use of these technologies.

2. Methodological framework

With the purpose to achieve the outlined objectives, three set of methodologies have been used. The selected evaluation criterion for this study was, firstly the economic efficiency/viability measure using partial budget analysis tool with the CBA as the key indicator. This is an evident indicator arguing that a technology that generates higher net benefits is more efficient than the one generating less or negative net benefits. The second method used in this research is the ADOPT framework; a Microsoft Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a target population – in this case AP farmers. The third method consists of using the Likert-scale method; which measures the attitude and perception of researchers and extension agents, rating the degree to which they agree or disagree with the defined characteristics of the ICARDA-APRP technologies. The following sections present and discuss the two applied methods.

2.1. Cost-benefit analysis tool

CBA is a basic approach in neo-classical economics adapted by environmental economists for the evaluation of net social or private welfare from environmental remediation projects; it is a systematic approach to estimating the strengths and weaknesses of alternatives that satisfy transactions, activities or functional requirements for a business. It is also a technique used to determine options that provide the best approach for the adoption and practice in terms of benefits in labor, time and cost savings etc. The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a project, decision or government policy.

According to Harberger (1971), the CBA is considered one of the basic postulates of applied welfare economics. There are many justifications for this, but according to Boardway (1974) the one that appeals most to 'objective' economists is that aggregate monetary gains and losses measure the efficiency of a project. If the aggregate is positive, it implies that the gainers could compensate the losers and still be better off after the project is undertaken and vice versa. De Graaff and Kessler (2009) argued that the eventual aim of CBA is a comparison between the present value of the streams of benefits (positive effects) and the present value of all investment and recurrent costs (negative effects). In a typical CBA, the costs of the inputs are assessed and compared to the monetary estimates of total benefits that the project is expected to provide. The evaluation process consists of several stages, each paying attention to such details as totaling the benefits and costs accruing to different groups or persons in different time periods.

The essential theoretical foundations of CBA: benefits are defined as increases in human wellbeing (utility) and costs are reductions in human wellbeing. For a project, to qualify on cost benefit grounds its net benefits must exceed its net cost. Broadly, CBA has two purposes:

- To determine if it is a sound investment (justification and feasibility), to provide a basis for comparing projects; it involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.
- CBA is related to, but distinct from cost-effectiveness analysis. In CBA, benefits and costs are expressed in monetary terms, then adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their "net present value".

CBA in the context of this research was employed to evaluate the on-site losses and gains associated with adopting improved technologies in ICARDA's A regional program (such as soilless systems, IPPM and cooled versus net houses in protected agriculture, irrigated native forages, spineless cactus, RR) with a particular target population (in each AP country). The scale of the CBA in this study is the farm level and the objective is to conduct a financial analysis of the gains and losses from the adoption of the six implemented technologies. CBA is used here as decision tool after computing all cost and benefits valued in local currency for each country and converted to US dollars.

The selected evaluation criterion for this study was the economic efficiency/viability measure using CBA. A technology that generates higher net benefits is more efficient than a technology that generates less or negative net benefits. This criterion was selected considering the main objective of this research.

2.2. Adoption and Diffusion Outcome Prediction Tool (ADOPT)

The use of new agricultural technologies has been found to be a function of farm and farmer characteristics and specific features of the technology (Feder et al., 1985; Marra and Carlson, 1987; Rahm and Huffman, 1984). A considerable set of literature has been developed regarding factors that influence the adoption of new technologies by farmers using innovation theory (Feder et al., 1985; Griliches, 1957; and Rogers, 1995). Adoption and diffusion theory also have been widely used to identify the factors that influence an individual's decision to adopt or reject an innovation. Rogers (1995) defined innovation as "an idea, practice or object that is perceived as new by an individual or other unit of adoption. The perceived newness of the idea for the individual determines his or her reaction to it."

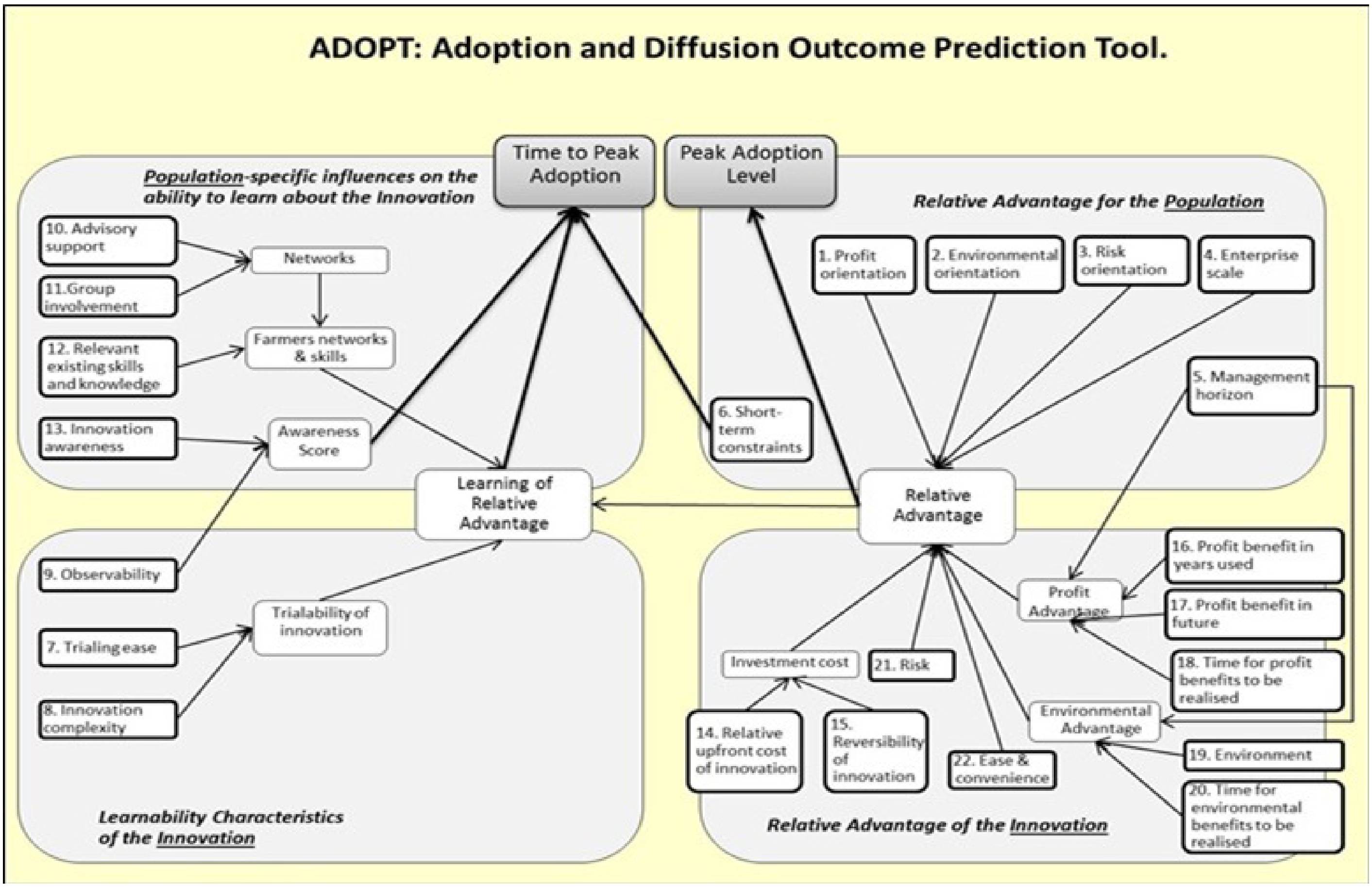
ADOPT[1] is a Microsoft Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a particular target population in mind. The tool uses expertise from multiple disciplines to make the knowledge surrounding the adoption of innovations more available, understandable and applicable to researchers, extension agents and research managers. ADOPT predicts the proportion of a target population that might adopt an innovation over time and makes the issues around the adoption of innovations easy to understand. The tool is useful for agricultural research organizations and people interested in understanding how innovations are taken up.

The tool has been designed to:

- **Predict** the likely peak level of adoption of an innovation and the time taken to reach that peak.
- **Encourage** users to consider the factors that affect adoption at the time that projects are designed.
- **Engage** research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable.

1 All information concerning how ADOPT works was found at: http://aciar.gov.au/files/node/13992/adopt_a_tool_for_evaluating_adoptability_of_agric_94588.pdf

Figure 1. Adoption and diffusion outcome prediction tool (ADOPT).



Source: http://aciar.gov.au/files/node/13992/adopt_a_tool_for_evaluating_adoptability_of_agric_94588.pdf.

ADOPT users respond to qualitative and quantitative questions for each of 22 variables influencing adoption. Going through this process also leads to increased knowledge about how the variables relate to each other, and how they influence adoption and diffusion. ADOPT is structured around four categories of influences on adoption (Figure 1):

Learnability of the population

Concerns the characteristics of the population that affect their ability to learn about the innovation. There are four questions regarding this aspect of adoption: which focus on group involvement in the community relevant to the innovation; whether or not the populations use advisors to get relevant advice about the innovation; the relevant existing skills or knowledge in the population; and, the awareness of the innovation in the population.

Learnability of the Innovation

Refers to the characteristics of the innovation itself that determine a group's ability to learn about it. Three factors are used to determine this aspect of the adoption process: the ability to run small trials of the innovation; whether the innovation requires complex changes to the farmland for implementation; and, the level of observation of the innovation.

Relative Advantage for the Population

Attempts to determine whether the advantage that the population could gain from the innovation is satisfactory to be encouraged to adopt the innovation. To assess this aspect, the program asks six questions which review the following: the number of farmers that could benefit from the innovation; the extent to which farmers use long-term planning; how much the farmers' decisions are motivated by maximizing profits; how much the farmers' decisions are motivated by protecting the environment; the community's level of risk aversion; and, short-term financial restraints.

Relative Advantage of the Innovation

Looks at the objective advantages of the innovation without considering the community's perception of the innovation. This part of the process is assessed through eight questions, which deal with: the initial costs of implementation; whether or not implementation can be reversed to allow for other innovation options; overall change in profit to the farms from the innovation; how long it will take for the change in profit to take effect; whether or not the innovation decreases farmers' vulnerability to seasons with difficult conditions; the advantages and disadvantages to the environment as a result of implementation; how long until the environmental effects are noticeable; and, the non-monetary benefits of the innovation to the farmer.

This tool was used to evaluate and predict the likely level of adoption and diffusion of the improved technologies in ICARDA's AP regional program (such as soilless systems, Integrated production and pest management and cooled versus net houses as associated technologies to protected agriculture, IF, SC and RR with a particular target population (in each AP country). ADOPT predicts the proportion of a target population that might adopt an innovation over time.

2.3. Likert-type scales

Developed in 1932 by Rensis Likert to measure attitudes, the typical Likert scale is a five- or seven-point ordinal scale used by respondents to rate the degree to which they agree or disagree with a statement. In an ordinal scale, responses can be rated or ranked, but the distance between responses is not measurable.

To assess the perception of the AP researchers and extension agents on the key characteristics of the ICARDA-APRP technologies, in this study, we applied the six-point Likert scale, which are ordinal scales used to determine researchers and extensionists levels of agreement or disagreement on opinions and perceptions towards technology characteristic component (where scoring 'one' refers to a respondent not sure or not applicable with a statement and six rates the respondent strongly agrees with the same statement). Descriptive statistics and reliabilities scores were calculated for each scale of the technology characteristics item. Consequently, a composite index (measuring the collective stance of the stakeholders and weighted score for each characteristic) have been calculated for measuring the stakeholder's perceptions between and within the AP countries.

The evaluated technologies characteristics scored by using six-point Likert scale were the following: divisibility of the technology; compatibility of the technology; communicability of the technology; easy to follow up; easy to implement; environmental benefits; reduce risk; increase profit; reduce costs; affordability of the technology; complexity of the technology; and finally, if the technology need skills know.

3. Data and sources of data

Data collection and Cost benefit analysis: for the cost benefit analysis, it is worth indicating that the unit of analysis in this study was formed by heads of household who were farmers adopting one of the targeted technologies indicated above. In a first step, this analysis was conducted only for Yemen. A rapid agro-economic survey was conducted on selected farms. A survey questionnaire was administered (by the researcher and field assistance) to selected farmers in the target areas. Data on the following farm level issues were elicited from smallholder farmers within the target sites: labour resources; farmland characteristics; crop yield and prices; crop production (i.e. investments on crop production). This survey collected the necessary quantitative data for the financial CBA. The financial CBA aided the discussion on the costs and benefits associated with the adoption of the following technologies: sorghum vs clitoria e; local buffel grass (libid) vs gayanda libid in forage production; soil vs soilless technology; and IPPM technology in protected agriculture. Data solicited from farmers was analyzed (for the financial cost benefit analysis) using Microsoft Excel.

Data collection and ADOPT analysis: regarding the implementation of ADOPT, we used an FGD methodology (Krueger, 2002)) to apply the ADOPT (Kuehne et al., 2013) with group farmers some of them are involved in the project activities. The number of farmers in the focus groups vary between the countries and for the tested technologies. We streamlined 22 discussion questions around four categories of influences on adoption: (i) characteristics of the innovation; (ii) characteristics of the target population; (iii) relative advantage of using the innovation; and, (iv) learning of the relative advantage of the innovation. The format of the discussion group consisted of both analytical questions (i.e., they discuss and collectively decide what they believe the answer is), and clarifying questions (i.e., questions that help clearing up confusion and explain why they had chosen this answer). Farmers were asked to think about their problems related to implementing the ICARDA-APRP technologies and the most challenging for them.

Data collection and Likert-type scale (LS) analysis: to implement the LS tool for measuring AP researchers and extension agents' perception and agreement with the twelve technology characteristics and for identifying the critical constraints to the adoption of such technologies, a survey response using scale categories ('one' refers to a respondent not sure or applicable with a statement and 'six' rates the respondent strongly agrees with the same statement) has been conducted in 2017 and targeted the agricultural R&E centers managers in the seven AP countries . A total of seven R&E centers in each one of the seven AP countries participated in this survey.

4. Results and discussion

The general assessment of the technologies introduced by the ICARDA-APRP indicates that AP farmers believed that the introduced technologies are useful for them because they fit very well with their environmental and socio-economic conditions; they give higher yields with less water, less pests, and consequently more profit. Farmers prefer technology with fewer inputs (mainly in labor and in the use of chemicals and pesticides) but with a large interest in ensuring high productivity; they also prefer more flexible and less sophisticated technology; and, they expect to have more knowledge and know-how through more efficient extension systems precisely about some technologies such as soilless culture regarding their technical and commercial aspects.

In the section below, we present and discuss the results of the main findings related to the economic evaluation and profitability of the implemented technologies, the prediction of their adoption levels from the farmers' (end users) perspective, taking into consideration the main factors that could influence the adoption and dissemination of these innovations, and finally their basic criteria assessment from the researchers and extension agents' point of view.

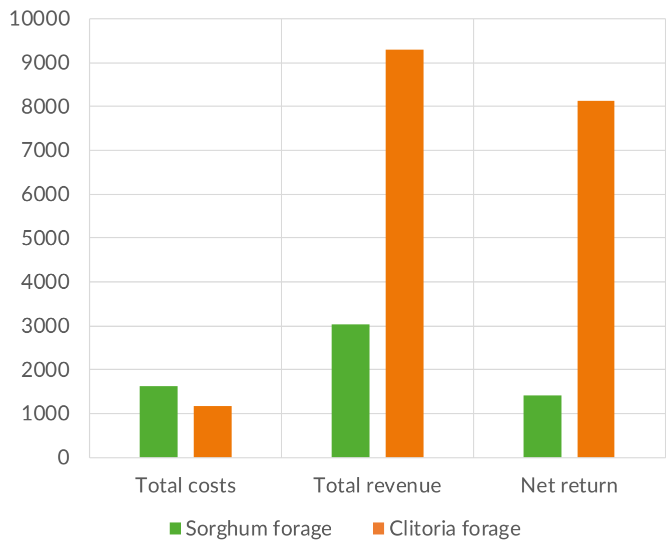
4.1. Cost benefit analysis of the adoption of the ICARDA's APRP improved technologies

The results of the CBA for the technologies implemented in Yemen case are discussed in this subsection. The comparison between the costs and benefits between the sorghum (seasonal grass forage) and the improved forage named Clitoria (perennial legume forage) indicates a clear profitability for this latter. Results indicate that, on average, the adoption of Clitoria, a protein rich forage, implies a reduction for about 39% in the total costs (Figure 2). The results also demonstrate an increase of about 207% and 479% for the revenue and net return respectively. These findings are confirmed by the high BCR when adopting Clitoria (7.97) in comparison with the farming of sorghum (1.86). The major perceptible benefit, in addition to reduce the total costs and increase the total revenue, is the amount of water saved when adopting this technology (reduction of about 48%). The visibility of these benefits could be in the future the key for the public extension services to enhance the adoption of this technology and to encourage farmers to adopt it. This technology could also be scaled-up to other regions with similar socio-environmental contexts across the AP region.

The empirical findings on the disaggregated costs and benefits assessment between the local variety of buffel grass (*Cenchrus ciliaris*), known as Libid, and an introduced variety called Gayanda are presented in the Figure 3. The main appraisal indictors (net revenue, CBR and IRR) indicated the high profitability when adopting this introduced variety of Libid. The corresponding CBR is around 22.32 among farmers who adopted Gayanda against 18.35 among farmers who practice local Libid forage. Findings indicate although we noted a slight increase in the total costs for the adopters of such technology, the net return increases hugely to about 126%. The major benefit to adopting this technology is the high level of revenue, due to the increase in yield. Therefore, the tangible benefit from this technology is the high amount of forage produced per hectare multiplied by its unit price during the period of analysis.

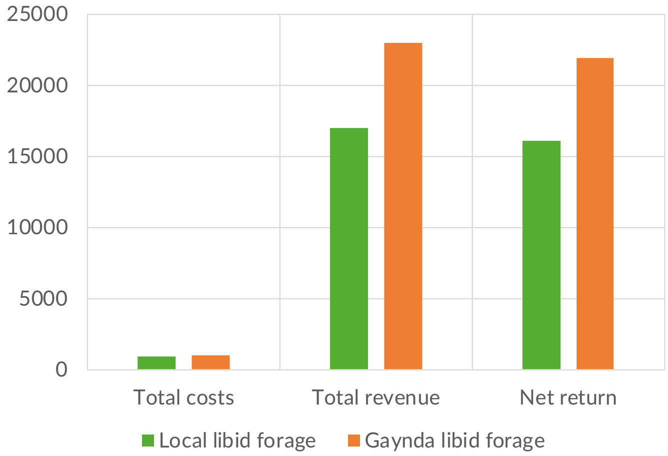
The third technology evaluated is SPS (hydroponics), against the soil (as opposed to soilless) production system in protected agriculture. This technology was introduced to the farmers with the purpose to enhance the sustainability of their farming systems through an efficient use of resources, mainly water. The empirical findings indicate that CBR for the adopters of this technology for the cucumber crop is an average of 2.91,

Figure 2. CBA – Sorghum vs Clitoria forage (US$/ha).



Source: Own elaboration from countries reports (2016).

Figure 3. CBA – Local buffel grass vs Gayanda (exotic) libid forage (US$/ha).

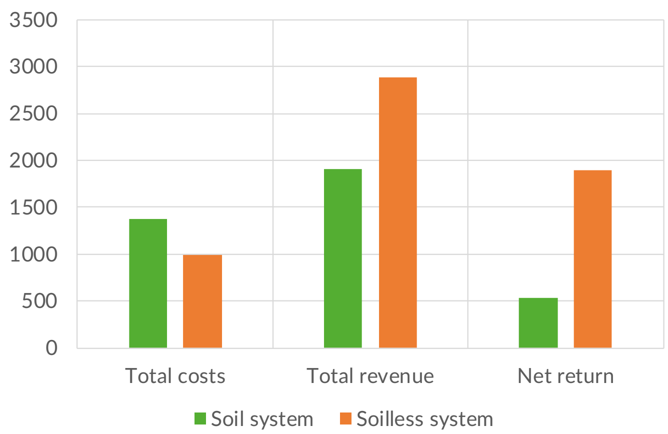


Source: Own elaboration from countries reports (2016).

whereas this ratio is almost 1.4 for the farmers keeping the soil production system. The tangible benefit from the adoption of this technology is, in addition to the high level of productivity and production, the conserved amount of water (around a 200% saving in comparison to the soil production system). By applying this technology the net return per hectare is increased by 260% (Figure 4); this increase in income, in addition to the considerable amount of water saved, highlighted the need to enhance the awareness of farmers regarding the profitability of using this technology (both economically and environmentally), in comparison to the traditional soil system, through an effective extension service to provide know-how and to facilitate the use and large diffusion of this technology.

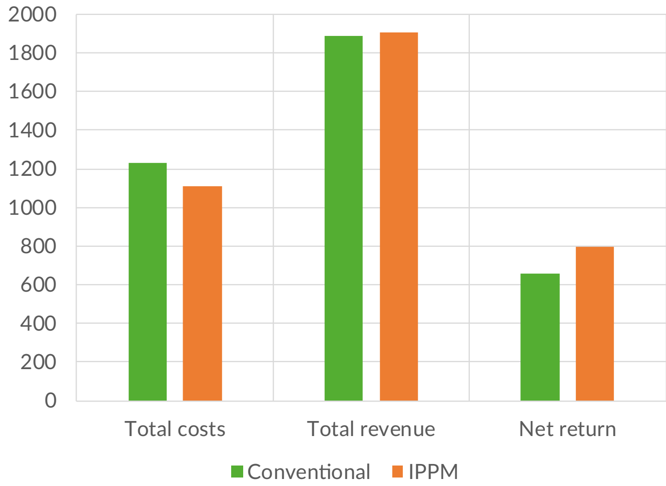
The interventions introduced by the project in using IPPM were subjected to economic analysis using partial budgeting analysis, by comparing the adoption of the

Figure 4. Soil vs soilless system for cucumber (US$/ha).



Source: Own elaboration from countries reports (2016).

Figure 5. CBA – Conventional vs IPPM for cucumber (US$/ha).

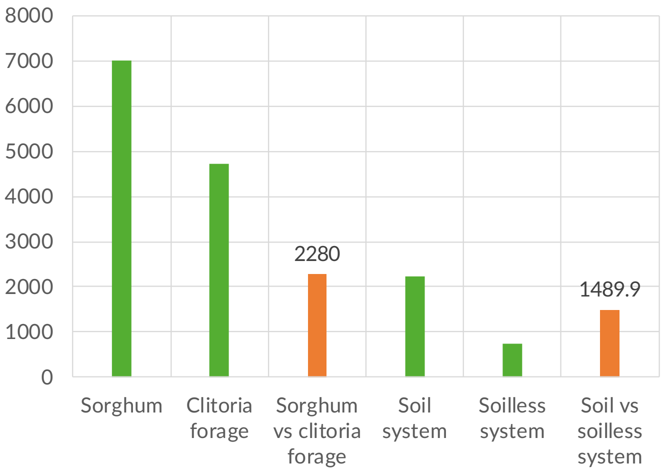


Source: Own elaboration from countries reports (2016).

IPPM package with the common practices of chemical pesticides or no pest control. The analysis showed that using IPPM increased yields by 15% per ha compared to yield with chemical pest control and gave a reduction in total costs of about 11% (Figure 5). Economic analysis showed that the net benefit to cucumber growers by applying IPPM technology was US$1,903. These results are confirmed by the BCR indicators, which is around 1.72 among farmers who practiced the IPPM against 1.53 among farmers who did not practice it. The adoption of such technology offers an opportunity to arrest and reverse the downward spiral of resource degradation, protect the environment (less chemical use), lower cultivation costs and make agriculture more resource-efficient (irrigated water) and sustainable for the cucumber growers in Yemen (Figure 6).

In summary, there is clear evidence for the economic profitability of the above assessed technologies. The project results suggested that sustainable increases in productivity of crops and forages can be achieved, the environment is better protected, and an important quantity of water can be saved if farmers and growers can be encouraged to adopt the improved technology packages. The benefits of this technology must be clearly perceived by farmers given their own socio-economic conditions. However, the adoption of such a technology needs to be accompanied by a supporting extension system and an enabling political environment to ensure the scaling-up and widespread use of this promising and profitable technology. In AP countries, increasing farmers' knowledge and perception of the

Figure 6. Water use gain through improved technologies (m^3/ha) (clitoria forage vs sorghum and soil vs soilless system).



Source: Own elaboration from countries reports (2016).

merits of the technologies, through better access to technical information, extension, and training, will help them to develop a positive economic and environmental assessment of the proven technologies.

4.2. Prediction of adoption levels and factors affecting the adoption ICARDA's APRP improved technologies

As indicated in the sections above, five characteristics of an innovation that affect an individual's adoption decision:

- Relative advantage: how the innovation is better than existing technology.
- Compatibility: the degree to which an innovation is seen as consistent with existing experiences, needs, and beliefs of adopters.
- Complexity: how difficult the innovation is to understand and use.
- Trialability: the degree to which the innovation may be used on a limited basis.
- Observability: the degree to which the results of an innovation are visible to others.

The assessment of the adoption levels including the factors affecting the adoption of each one of the technologies implemented by the project are discussed in the following section.

4.2.1. Predicted adoption levels and factors affecting the adoption of Soilless Production System (SPS) technology

The results of the focus group with farmers in Bahrain, KSA, Qatar and Yemen with respect to the adoption of SPS showed that the peak adoption rate for this technology is predicted to be 95%, 91%, 8% and 86% after a period of 17.5, 18.3, 19.2 and 18.5 years, respectively (Figure 7). With respect to Oman, the findings indicate a slight difference between the regions on the predicted level of SPS. This difference is due to the socio-demographic and -economic conditions of the growers and to the farming system practiced in each region (Figure 8).

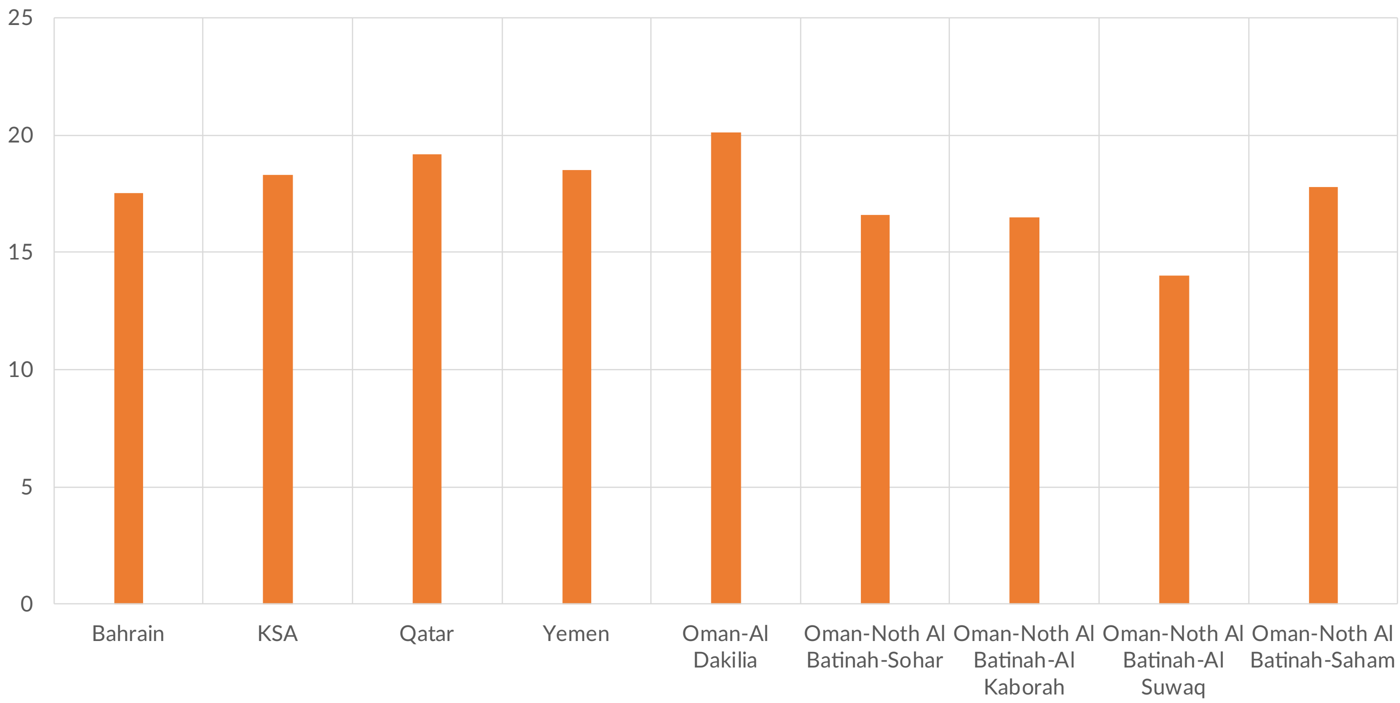
According to factors affecting both the peak of adoption and the time to reach it, results from the sensitivity analysis indicate that trialability of the technology, in addition to its complexity where the influencing effects of its use, and consequently they are considered the main factors constraining the widespread of such technology for the considered countries. Nevertheless, in Bahrain, the adoption of the soilless system is affected negatively by the fact that it is not observable by the farmers (who are yet to adopt it) when it is used in their area.

In Yemen, in addition to the factors mentioned above, three factors are specific to the Yemeni growers that affect the technology of the considered technology: the risk; investment cost; and, its profitability in the years that is used. In Qatar, an additional factor such as the need to develop substantial new skills and knowledge to use the innovation. This factor also influences the time to peak the adoption of SPS in Oman (including the regional adoption). This result highlights the need to enhance the agriculture system to provide technical assistance for the users of this technology in all the regions.

4.2.2. Predicted adoption levels and factors affecting the adoption of Integrated Production and Protection Management (IPPM) system technology

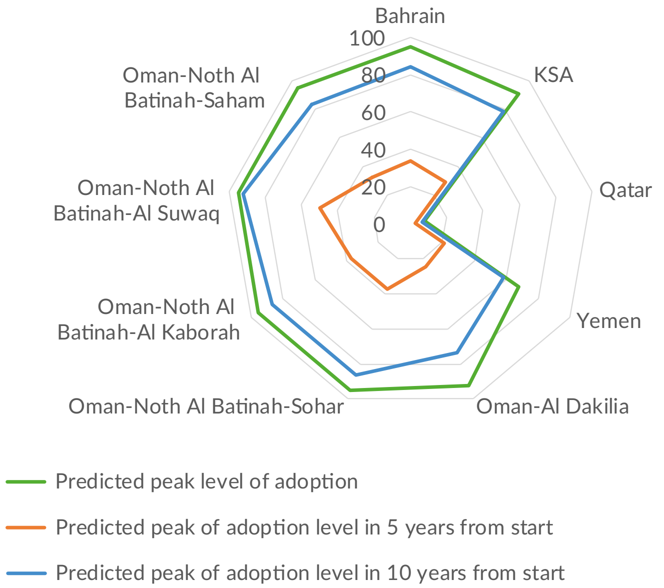
One of the major objectives of the ARPR is to disseminate the IPPM technology package. This technology aims to reduce costs, increase the productivity of small farmers, and protect the environment. The assessment results of the adoption of this technology with special emphasis on the main constraining factors affecting its adoption are displayed in Figure 9. Results showed the peak adoption rate for Bahrain, KSA, and Yemen for this technology is predicted to be 95%, 94% and 85% after a period of 11.2, 21.6 and 13.8 years, respectively. After five years from the start, the predicted adoption level is quite

Figure 7. Predicted years to peak adoption of SPS (years).



Source: Own elaboration from countries reports (2016).

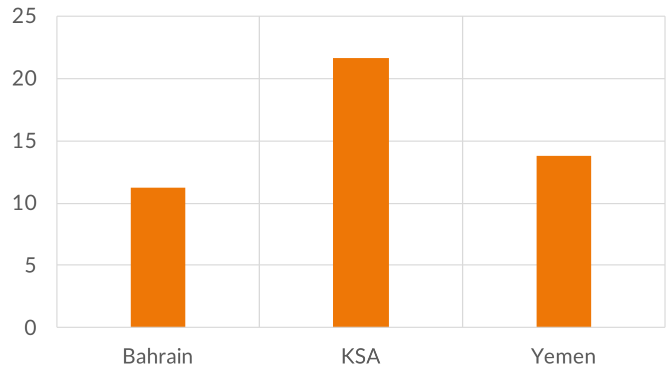
Figure 8. Predicted peaks levels for adoption of SPS (%).



Source: Own elaboration from countries reports (2016).

acceptable for Bahrain and Qatar compared to KSA, where this predicted level is very low. Furthermore, this level remains low after 10 years from the startup of the adoption process. This could be explained by the existence of many constraints which prohibit the adoption and mainly affect the time to peak adoption level (Figure 10).

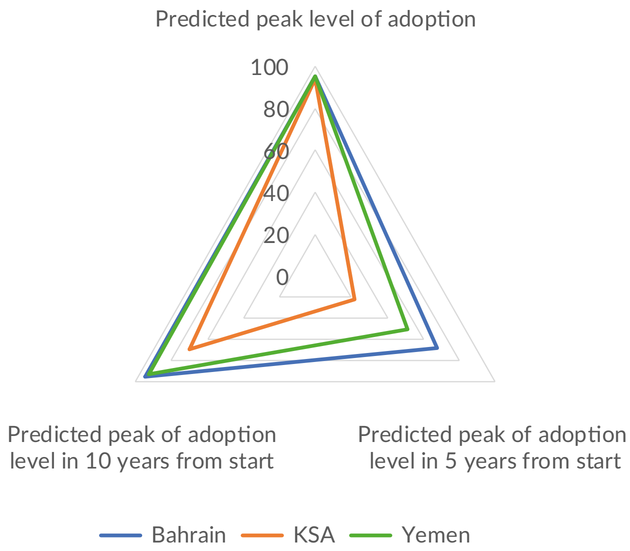
Figure 9. Predicted years to peak adoption of IPPM (years).



Source: Own elaboration from countries reports (2016).

The discussion with farmers reveals that, short-term financial constraints of the farmers, the trialability of the technology, its complexity, lack of an effective advisory service, lack of know-how for using the technology and the up-front cost relative to the potential annual benefit by using this IPPM technology, are the major constraints to adopt and widespread it. The outlined factors are also raised by the Yemeni farmers. Thus, for further expansion of this technology, there is a need for an enabling environment policy enhancing the use of organic sources and reducing the use of chemicals in the indicated countries.

Figure 10. Predicted peaks levels of adoption of IPPM (%).



Source: Own elaboration from countries reports (2016).

4.2.3. Predicted adoption levels and factors affecting the adoption of Irrigated Forages (IF) technology

The localized irrigation for forages crops, and on-farm water management is an integrated technology introduced by the project and it is considered as a proven technology given its profitability both economically and environmentally. The aim is to reduce the quantity of water used for irrigation and to increase the profitability for the small farmers. Empirical findings from the identification and the analysis of the factors leading to the adoption of this technology, with emphasis to the predicted level of adoption and the time to peak such adoption after five and ten years from the start are presented in the Figure 11. The results presented in this figure show a similarity in the years to peak adoption in KSA, Qatar and Yemen (for Clitoria forage) where this peak (95%) is expected to be after 13.5, 14.6 and 13.2 years, respectively. In the case of Yemen, this peak is predicted for buffel grass to be after 17.3 years (Figure 12).

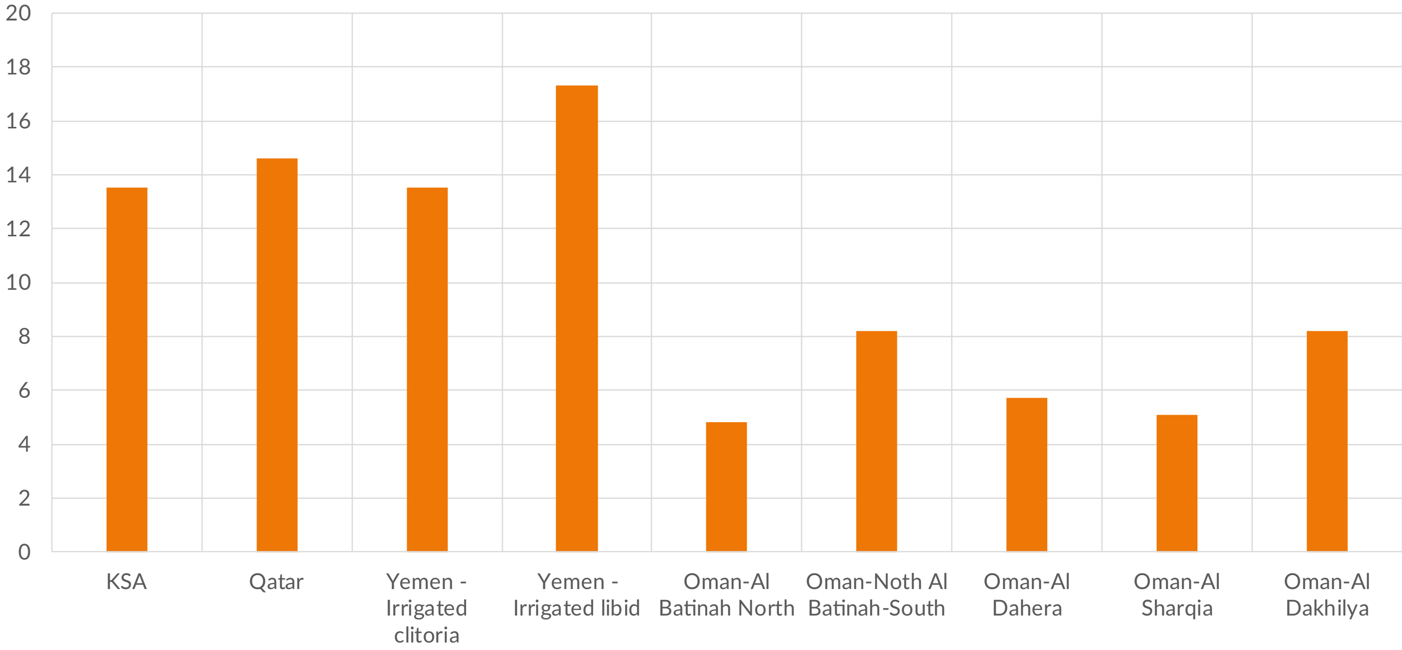
In Oman, we note that this peak can be reached in a shorter time compared to the rest of the AP countries; where it is expected to be around five years for the northern region and between six and eight years for the southern region. This variability is due to the natural environment of the northern region of Oman which is characterized by important water and animal resources that enhance the adoption of this technology.

The results indicate that there are number of factors that influence the extent of adoption of technology such as characteristics or attributes of technology; financial factors, the change agent (extension system, professional, etc.); and, the socio-economic and physical environment in which the technology takes place. Thus, it is imperative to create favorable conditions so that a greater number of farmers can take advantage of these technologies. Furthermore, on the most important steps towards this goal is to identify the factors encouraging the adoption of highly water-efficient IF. The results displayed in Figure 4 leads one to confirm that any action should only take into consideration factors that can stop change only in time to attain a peak adoption level, as no factors can change the peak adoption level. Empirical findings reveals the following factors influencing the adoption of this innovation: Severe short-term financial constraints; trialability of the technology before taking a clear decision to be adopted; its complexity; observability to farmers who are yet to adopt it when it is used in their area; paid advisors capable of providing advice relevant to the innovation; needs to develop substantial new skills and knowledge to use the innovation; and the size of the up-front cost of the technology relative to the potential annual benefit from using it. Thus, the farmers' skills and networks, the trialability of the innovations, combined with the relative advantage of the innovations make up the population's ability to learn about the innovations, and this, combined with the factor of short-term financial constraints, determines the time to peak adoption. In these countries, increasing farmers' knowledge and perception of the merits of water-efficient IF technology through better access to technical information, extension, and training is often cited as central to helping them develop a positive assessment of this proven and promising technology. However, any intervention should take into consideration the most important influencing adoption factors, region specificities and farmers' preference.

4.2.4. Predicted adoption levels and factors affecting the adoption of Spineless Cactus (SC) technology

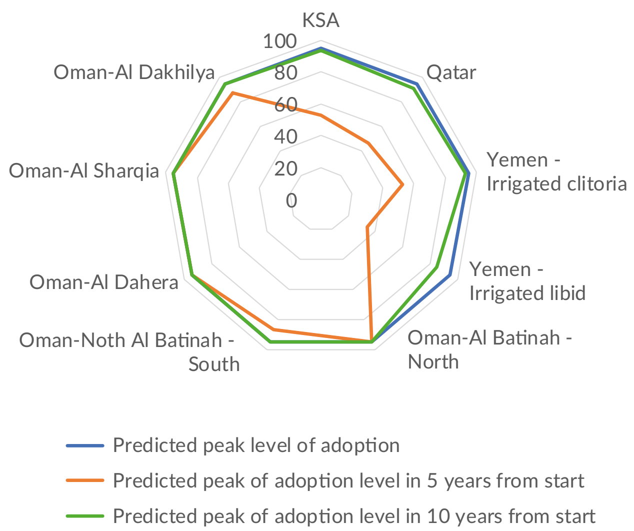
The peak adoption rate for the adoption of SC in Qatar is predicted to be 95% after a period of 9.4 years (Figure 13). The predicted adoption level in five and ten years from the starting period on the adoption of this technology is 80 and 90%, respectively (Figure 14). According to factors such as farmers' profit, environmental, and risk orientations, the number of farmers expected to benefit from the innovation – the environmental and profit advantages, the ease and convenience of implementation and use, and therefore the level of peak adoption of the innovations – is quite high.

Figure 11. Predicted years to peak adoption of irrigated forages (years).



Source: Own elaboration from countries reports (2016).

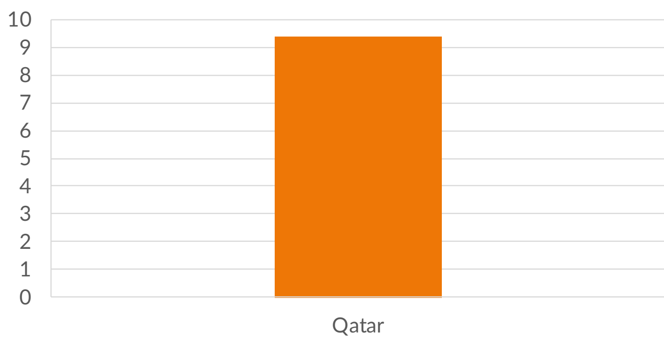
Figure 12. Predicted peaks levels of adoption of irrigated forages (%).



Source: Own elaboration from countries reports (2016).

The farmers' skills and networks, the trialability of the innovations, combined with the relative advantage of the innovations, make up the population's ability to learn about the innovations, and these factors determines the time to peak adoption. This result suggested the expected adoption of this technology in the future is quite promising and, therefore, its scaling-up should be accompanied by an effective and specialized extension system and an enabling policy environment, in addition to a financial supporting system given the high cost of rehabilitation.

Figure 13. Predicted years to peak adoption of SC in Qatar (years).

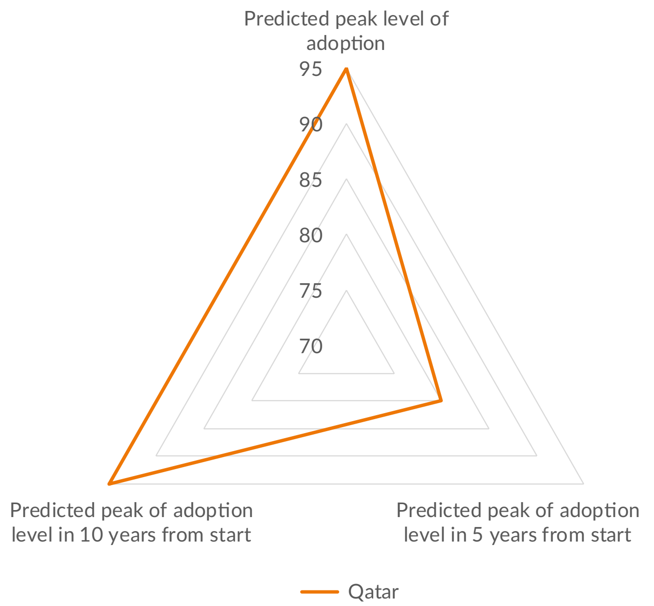


Source: Own elaboration from countries reports (2016).

4.2.5. Predicted adoption levels and factors affecting the adoption of Rangeland Rehabilitation (RR) technology

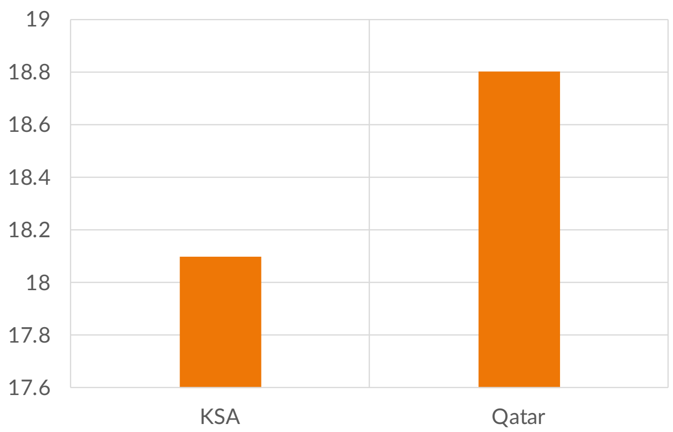
The analysis of the empirical findings presented in Figure 15 related to the predicted level of adoption for the RR techniques introduced within the framework of the project indicates a huge difference between KSA and Qatar on the predicted peak of adoption of this technology. Although, the predicted years to peak such adoption are around 18 years, the peak of adoption is expected to be 92% for KSA and 11% for Qatar (Figure 16). This predicted peak remains very low even during the first five and ten years for the case of Qatar.

Figure 14. Predicted peaks levels of adoption of SC in Qatar (%).



Source: Own elaboration from countries reports (2016).

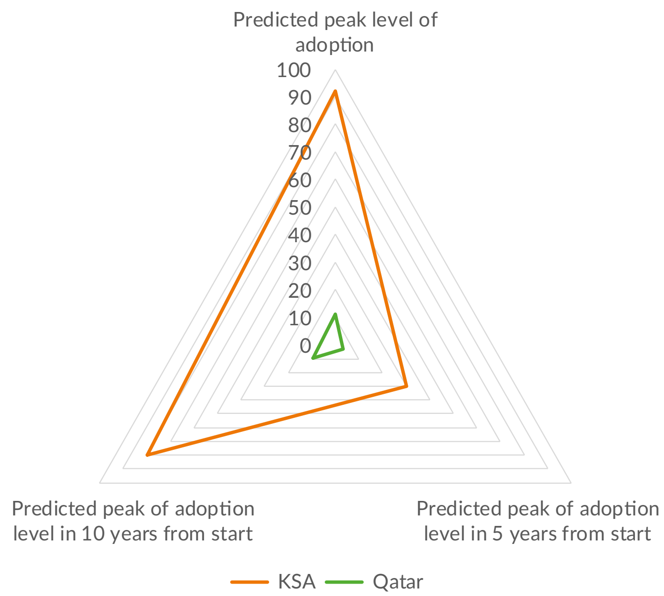
Figure 15. Predicted years to peak adoption of RR in KSA and Qatar (years).



Source: Own elaboration from countries reports (2016).

The sensitivity analysis reveals that many factors are contributing to or constraining this peak level of adoption, mainly for Qatar. These factors are the complexity of the innovation, its trialability, the need for farmers and communities to develop substantial new skills and knowledge to use the innovation as well as the up-front cost of the investment relative to the potential annual benefit from using this technology. This implies that decisions-makers should take into consideration those elements when developing extension programs and effective extension services in Qatar.

Figure 16. Predicted peaks levels of adoption of RR in KSA and Qatar (%).



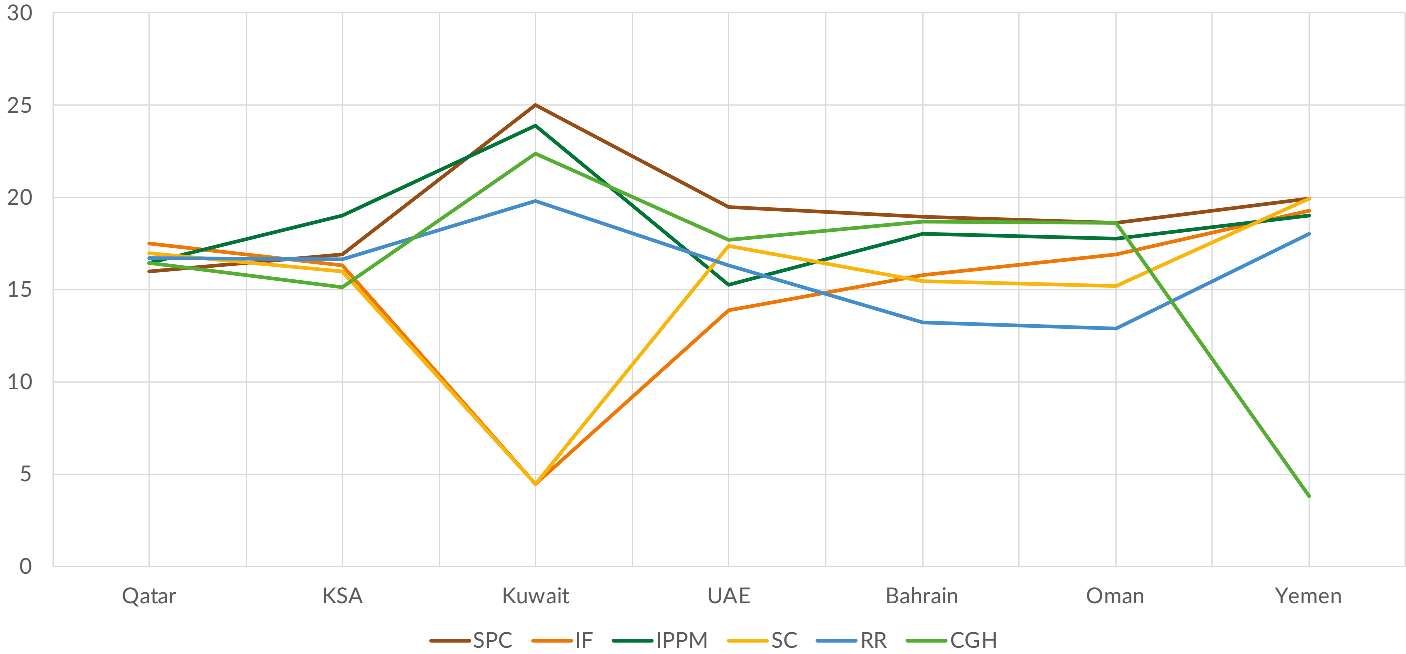
Source: Own elaboration from countries reports (2016).

4.3. Basic criteria and assessment of ICARDA's APRP improved technologies for adoption decision

In this analysis, we started first on making an overall assessment of the six implemented technology characteristics within each AP country. The twelve characteristics used are: (i) if the technology needs specific skills; (ii) if it is a complex technology; (iii) if it is affordable by small-farmers; (iv) if adopting this technology will reduce farming costs; (v) if the use of the technology will increase profits; (vi) if the technology reduces the risk in farming operations; (vii) if the technology is environmentally benefit; (viii) if the implementation of the technology is easy; (ix) if it is easy to monitor, to assess, and follow up; (x) if it is communicable; (xi) if it is compatible; (xii) and finally, if the technology is divisible.

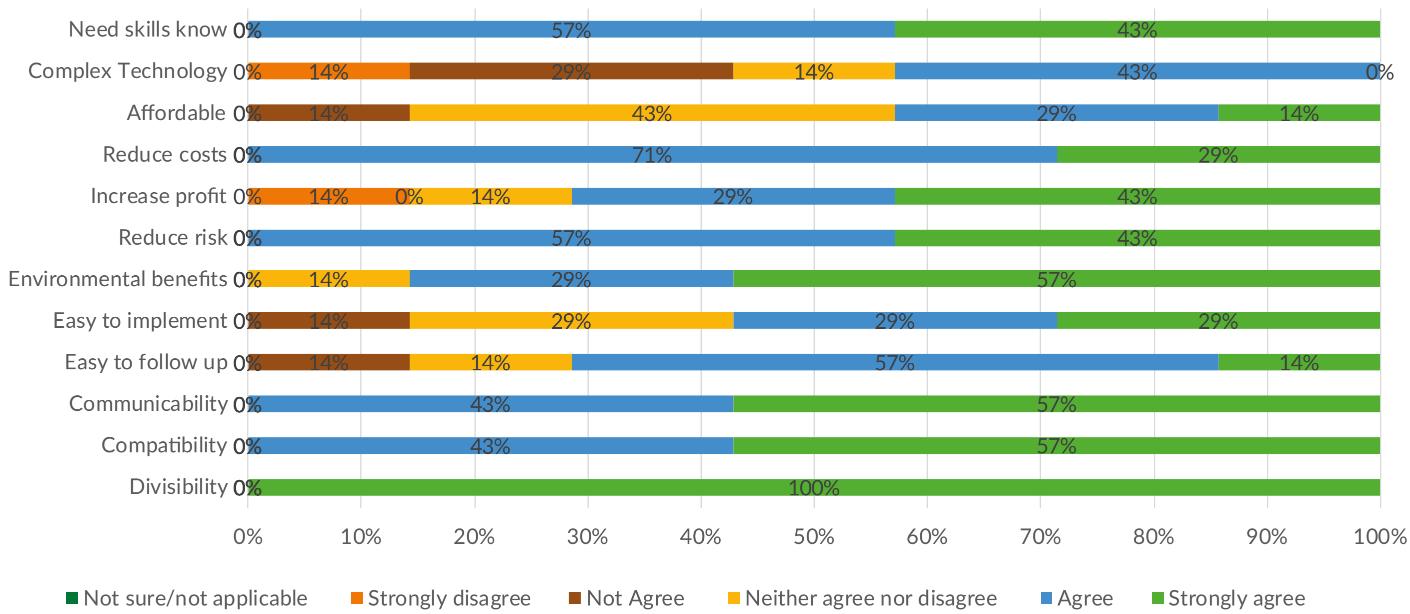
Results from this assessment are outlined in Figure 17; showing a clear convergence on the perception of researchers and extension agents among the AP countries regarding the SPS, integrated pest management, and RR technologies. In Kuwait, the IF and SC technology assessments are getting a low score, which is an indicator that these technologies are not well diffused and therefore an additional effort is needed to spread such technologies. The CGH technology is ranked with a low score in Yemen. This could be explained by the fact that adoption of this innovation is

Figure 17. ICARDA-APRP technologies assessment weight within each AP country.



Source: Own elaboration from countries reports (2018).

Figure 18. Net stacked distribution of the concerns over twelve major characteristics of the SPS technology.



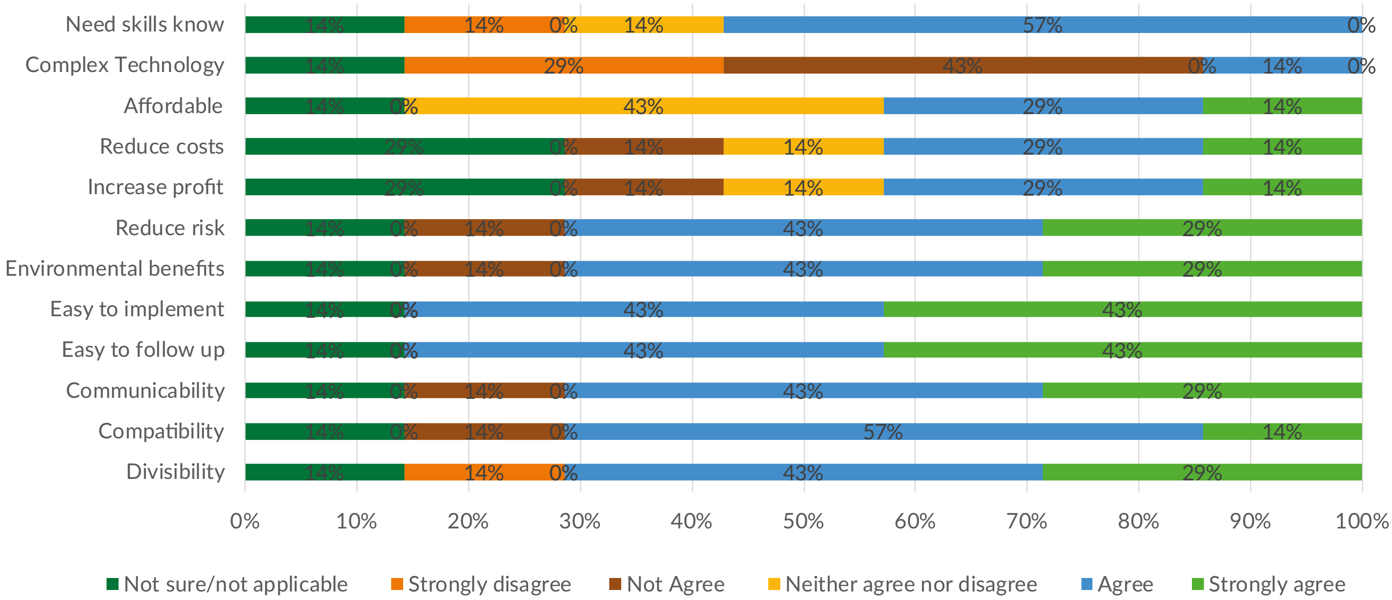
Source: Own elaboration from countries reports (2018).

very low as it is mainly constrained by the high level of up-front investment cost for this technology, making it unaffordable for small-farmers.

4.3.1. Soilless Production System (SPS): technology characteristics, R&E perceptions and adoption decisions

As shown in Figure 18, the study found that SPS technology needs skills knowhow. Economic features (reduced cost vs increase profit) are key determinants on the adoption of this technology, and consequently are enhancing actors for the development and dissemination of the technologies. About 71% of the researchers agree on the importance of this technology to reduce farming costs – the remaining strongly agree. From another side, 43% support the idea that adopting this technology could increase the profit of farming. The researchers also strongly agree on the environmental benefits of adopting this technology.

Figure 19. Net stacked distribution of the concerns over twelve major characteristics of the IF technology.



Source: Own elaboration from countries reports (2018).

Two elements could constrain the adoption of this technology: its complexity, as 43% consider this technology is complex for the small farmers; secondly, the diffusion of this technology is its affordability where almost 43% of the interviewers are not sure about this attribute, although from the other side around 43% consider this technology affordable. These findings are confirmed by the scores outlined in Annex 1-Figure 1. In summary, the SPS technology is ready to be diffused widely given its profitability (economic and environmental), as well as its impact and the short time to get benefit returns. SPS is also considered not only an income generating technology but also a labour generating technology (Annex 1-Figure 7).

4.3.2. Irrigated Forages (IF): technology characteristics, R&E perceptions and adoption decisions

The IF technology is perceived as the most profitable technology from economic, environmental and labour perspectives. Figure 19, Annex 1-Figure 2, and Annex 1-Figure 8 show the results of the assessment of the IF technology characteristics. The necessary skills knowhow was perceived as the key determinant by the researchers and extension workers in influencing the rate and speed of adoption of this technology. Moreover, this IF technology was perceived as easy to implement, to monitor, and to achieve its impact in short time. Knowing this, planners in R&E should advise and enhance the spread of this technology in the future.

4.3.3. Integrated Production and Protection Management (IPPM): technology characteristics, R&E perceptions and adoption decision

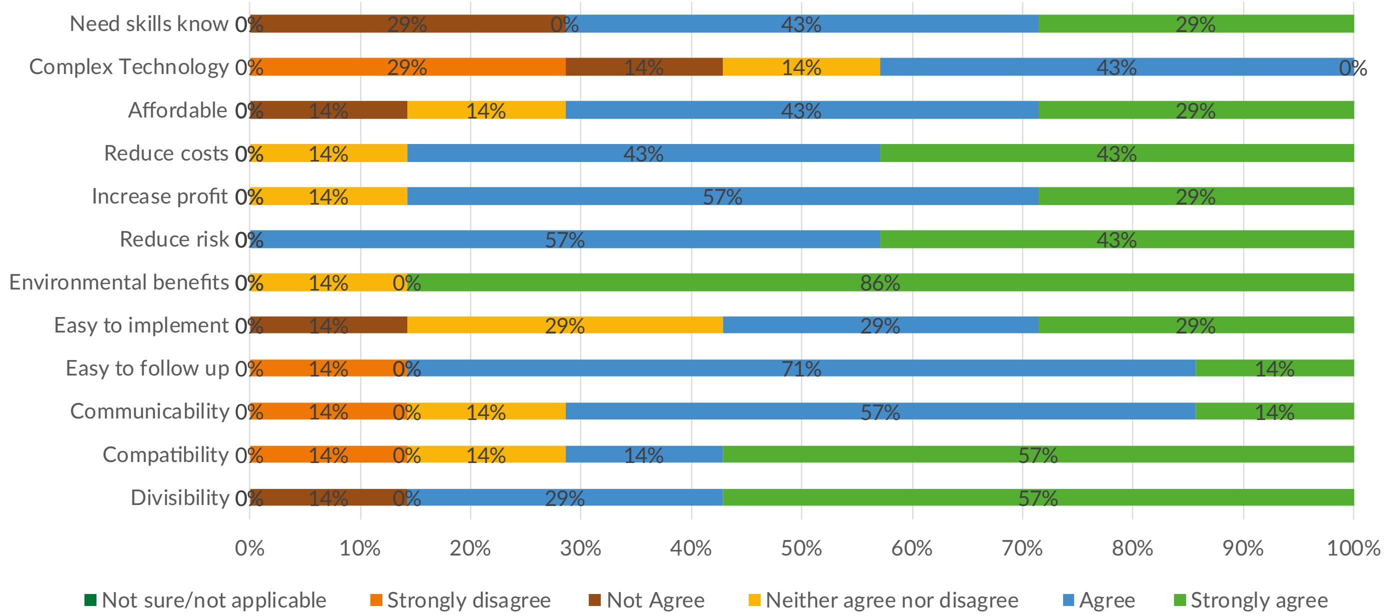
The below figure (Figure 20) shows how the characteristics of the IPPM technology could affect its rate and speed of adoption. Although perceptions of IPPM technology tend to be that it is affordable, reduces risk, environmentally beneficial, and increases farming profit, almost 43% of the researchers and extension workers consider IPPM a complicated technology; suggesting that decision-makers should advise on reducing management complexity of this technology.

The global assessment of these characteristics presented in Annex 1-Figure 3 and Annex 1-Figure 9 reveals the need to speed its diffusion given the potential of this technology to both generate incomes and contribute to job creation. Having this information and knowing which technology characteristics proved to be important for farmers decision-making will certainly allow decision-makers and planners in R&E to determine and target which characteristics of new technologies lead to their easy transfer and diffusion among the AP small-holding farmers.

4.3.4. Spineless Cactus (SC): technology characteristics, R&E perceptions and adoption decisions

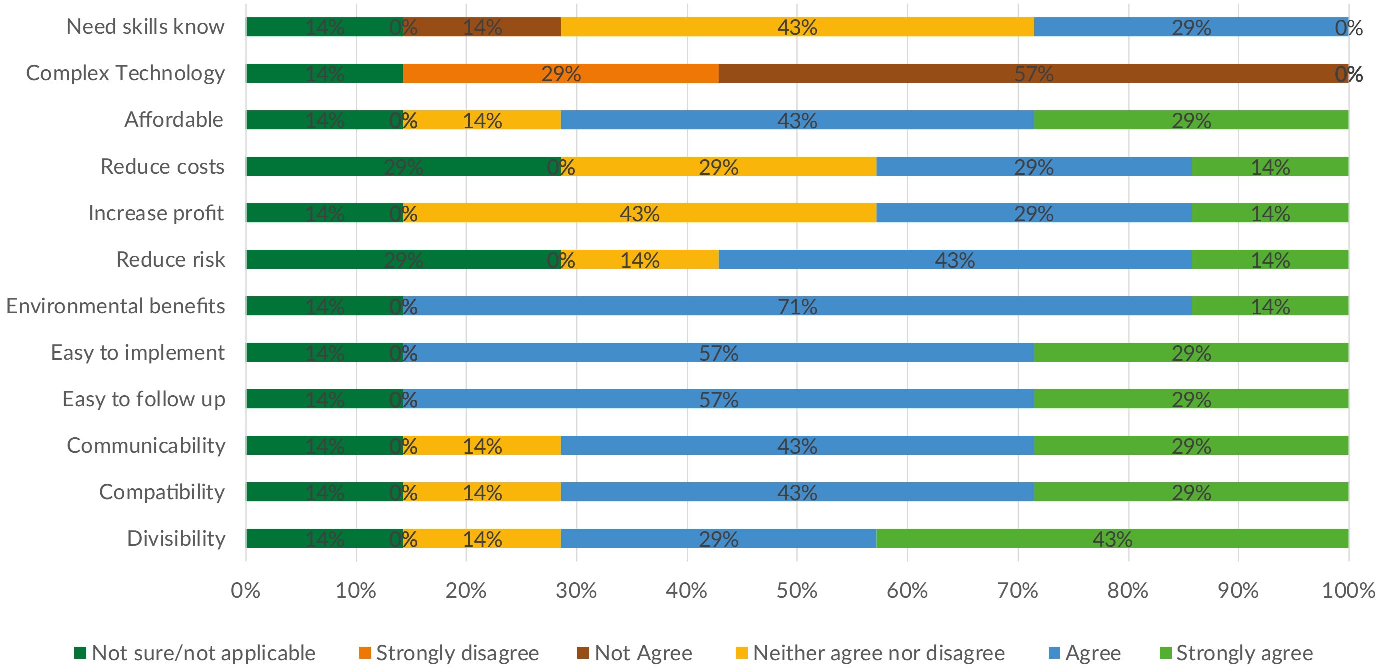
The technology diffusion of SC is still limited to a few PA countries (i.e. Qatar, Oman, and Yemen) and its spread in terms of general use and application is still limited, although SC is one of the best adapted plants for arid

Figure 20. Net stacked distribution of the concerns over twelve major characteristics of the IPPM technology.



Source: Own elaboration from countries reports (2018).

Figure 21. Net stacked distribution of the concerns over twelve major characteristics of the SC technology.



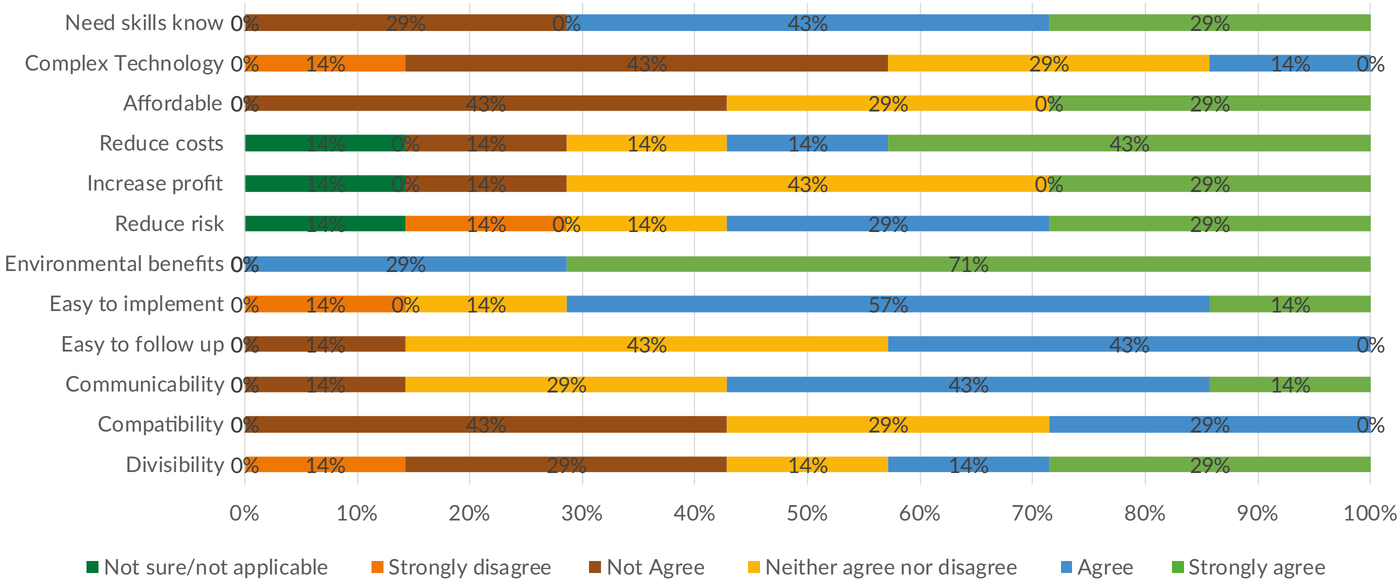
Source: Own elaboration from countries reports (2018).

and desert environments. SC is a good source of energy for livestock with a relatively low price and cost of production. In addition, we found a positive perception on the characteristics of this technology (Figure 210, Annex 1-Figure 4 and Annex 1-Figure 10) from researchers and extension workers which could influence both its diffusion and adoption. This perception highlighted the need to develop an integrated production system for SC to face high water requirement forages.

4.3.5. Rangeland Rehabilitation (RR): technology characteristics, R&E perceptions and adoption decisions

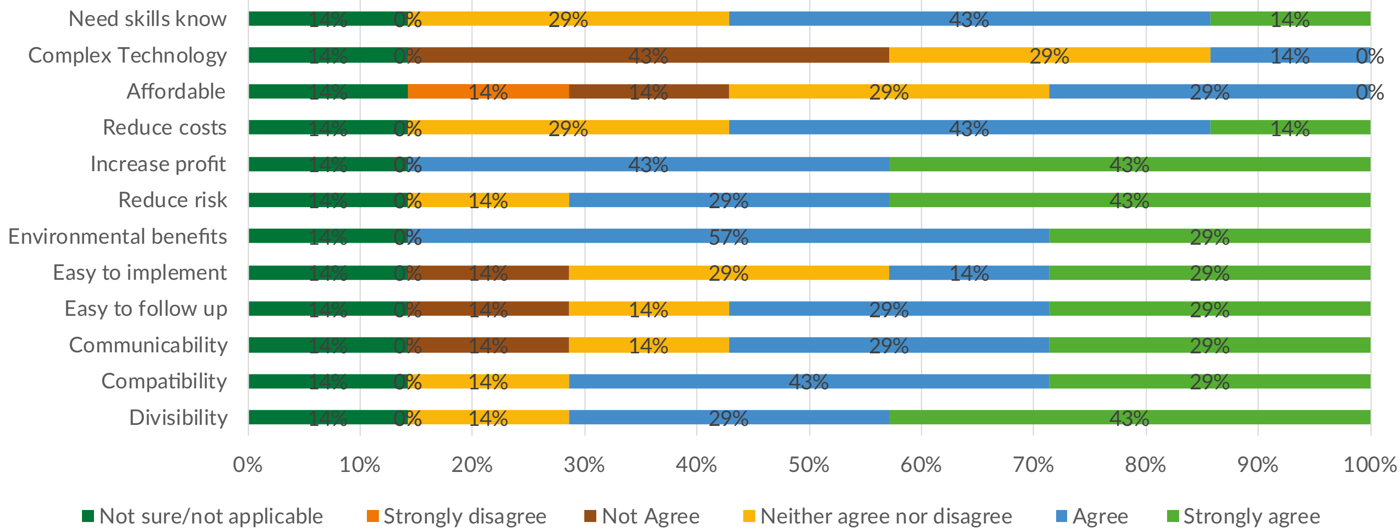
RR technology was perceived as a complex innovation (Figure 22) and the assessment of its adoption constraints (from farmers and communities' perspective) suggest the need for farmers to develop substantial new skills and knowledge to use the innovation. Another relevant economic factor is relative upfront cost of the practice, which captures the extent to which adoption

Figure 22. Net stacked distribution of the concerns over twelve major characteristics of the RR technology.



Source: Own elaboration from countries reports (2018).

Figure 23. Net stacked distribution of the concerns over twelve major characteristics of the CGH technology.



Source: Own elaboration from countries reports (2018).

of a RR practice requires upfront costs. The higher the upfront investment cost, the lower the relative advantage, other things being equal. A high upfront cost is more important to farmers' decision making if it is a long-term investment and it takes time to gain such as the case of RR technology.

RR is a beneficial technology in the long-term as much as it is supported by incentives mechanism system and strong implementation institution. The research findings imply that rangeland resource management technologies are suitable, relevant and could offer the means to improve agro-pastoral livelihoods (Annex 1-Figure 5 and Annex 1-Figure 11).

4.3.6. Cooling Green House (CGH): technology characteristics, R&E perceptions and adoption decisions

The assessment of CGH technology perception reveals its economic and environmental profitability (Figure 23).

Therefore, considering the speed to complete adoption, the influence of relative investment and implementation of this technology was higher, while relative complexity and risk showed significance. The strong influence of these characteristics of CGH as a technology on its adoption can be explained by the characteristics of farmers (small, business oriented) and the farming circumstances. Annex 1-Figure 2 indicate that CGH is a high remunerative technology, generating high profit and could contribute to job creation. The impact on adopting this technology is immediate and time to reach an impact is very low (as soon as it is adopted).

5. Concluding remarks and policy recommendations

Concluding Remarks

The economic evaluation, identification and analysis of factors affecting ICARDA's APRP technologies implemented in the frame of improving food security and sustainable natural resources management through "enhancing integrated agricultural production systems in the Arabian Peninsula" project leads to the following results:

- There is clear evidence that the economic profitability (reducing production costs and increasing net return) of these technologies are applied appropriately (e.g. Yemen).
- Suggest that a sustainable increase of vegetables crops and IF's productivity can be achieved.
- Also suggest that adopting IPPM and SPS will contribute to a better protected environment (e.g. reduction of chemical products) and more efficiency in water-use.
- Although the complexity of some technologies (e.g. rangeland management system), there is a willingness from farmers and growers to adopt them.
- The predicted level to attain peak adoption of these technologies is different between the AP countries and within the same country (i.e. Oman).
- The characteristics of the technology is a determinant on its level to attain peak adoption and on the time to attain a peak in the corresponding adoption level (low predicted level of adoption for the IF and high predicted level of adoption for the IPPM and RR).
- Technical assistance, substantial new skills and knowledge, up-front cost of investment, financial resources and effective extension advisory services are considered the main factors influencing the adoption of these technologies.
- The action on these factors will affect only the time to attain peak adoption levels of the said technologies.
- Characteristics of the technologies proved to be important for farmers' decision-making, which allows decision-makers and planners in R&E to determine

and target which characteristics of new technologies lead to their easy transfer and diffusion among the AP small-holder farmers.
- Farmers are encouraged to adopt these proven and promising technologies. In AP areas, increasing farmers' knowledge and perception of the merits of such technologies through better access to technical information, extension, and training will help them to develop a positive economic and environmental assessment of the proven technologies

Policy Recommendations and Practical Implications

Arising from the findings and conclusions of this research study, a number of recommendations are made as follows:

- Since these technologies meet the technical, economic, and socio-economic requirements, there is a need for a greater political and institutional input into these technologies, in particular: design and development of alternative policy instruments (other than subsidies) and institutions for a well-developed agricultural extension system that will facilitate adoption of APRP technologies. There is a need also to create a new price policy that gives higher prices for the IPPM products (or organic products). Furthermore, raising awareness for farmers and decision-makers on the environmental benefits by applying these technologies is needed to gain their support and confidence.
- The benefits (economic and environmental) of these technologies must be clearly perceived by farmers, given their own socio-economic, cultural and basic economic conditions. In AP areas, increasing farmers' knowledge and perceptions of the merits of these technologies through better access to technical information, know-how, effective extension delivery system, credit services, and training will help them to develop a positive assessment of these technologies.
- To accelerate the adoption process of these technologies, it is imperative to create favourable conditions so that a greater number of farmers can take advantage from the benefits of such technologies. A creation of a strong network among different institutions related to applying ICARDA-APRP technologies and involvement of public and private financial institutions and support services could be an example of mechanisms to enhance adoption. More specifically, linking mechanisms between R&E and extension education on ICARDA-APRP technologies would further push the adoption of such resource-saving technologies at farm level.
- It was clear that one of the most highlighted constraints to the adoption of agricultural technology is the up-front investment costs. A large investment costs may discourage adoption of some technologies (i.e. SPS) where farmers are unable to raise sufficient funds to invest in the mentioned technology. The higher the up-front investment cost, the lower its relative advantage. Thus, because of a lack of capital, limited access to credit, or temporary cash flow problems, a national supporting financial policy through small-holder credits, can be an important adoption driver to overcome financial constraints for investments in new technologies.
- There is a need for the promotion of collective actions (farmer groups) by farmers practicing their technologies to stimulate their demand and adoption countywide. Through these groups, farmers will be able to access credit, ease logistics involved in training and access markets for their outputs as groups.

Finally, there is a clear disparity at the regional scale, in the level of adoption and the factors affecting and encouraging the adoption of a specified technology (i, e. SPS and IF in Oman and Yemen). Thus, scaling-up and spreading it to other regions within the same country could be facilitated with interactive similarity maps that identify similar socio-economic and environmental contexts. Hence, only technologies with a high financial feasibility should be promoted and, therefore, farmers should be encouraged to join established and strengthened associations with access to extension information through which training, technical assistance and help can be provided. The policy implication that emerges from these findings is that action can only be achieved through both planned and designed programs in partnerships with all concerned organizations and by targeting the right beneficiaries.

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Annex

Table 1. ICARDA-APRP technologies assessment weight within each GCC country.

Countries	ICARDA-APRP Technologies					
	SPC	IF	IPPM	SC	RR	CGH
Qatar	15.94937	17.46835	16.4557	16.96203	16.70886	16.4557
KSA	16.91843	16.3142	19.03323	16.01208	16.61631	15.10574
Kuwait	25	4.477612	23.8806	4.477612	19.77612	22.38806
UAE	19.44444	13.88889	15.27778	17.36111	16.31944	17.70833
Bahrain	18.97106	15.75563	18.00643	15.43408	13.18328	18.64952
Oman	18.62464	16.90544	17.76504	15.18625	12.89398	18.62464
Yemen	19.93671	19.3038	18.98734	19.93671	18.03797	3.797468

Source: Own elaboration from survey data (2018).

Table 2. ICARDA-APRP technologies assessment weight between GCC countries.

Countries	ICARDA-APRP Technologies					
	SPC	IF	IPPM	SC	RR	CGH
Qatar	14.68531	20.05814	15.70048	19.36416	18.13187	18.00554
KSA	13.05361	15.69767	15.21739	15.31792	15.10989	13.85042
Kuwait	15.61772	3.488372	15.45894	3.468208	14.56044	16.6205
UAE	13.05361	11.62791	10.62802	14.45087	12.91209	14.12742
Bahrain	13.75291	14.24419	13.52657	13.87283	11.26374	16.06648
Oman	15.15152	17.15116	14.97585	15.31792	12.36264	18.00554
Yemen	14.68531	17.73256	14.49275	18.20809	15.65934	3.3241

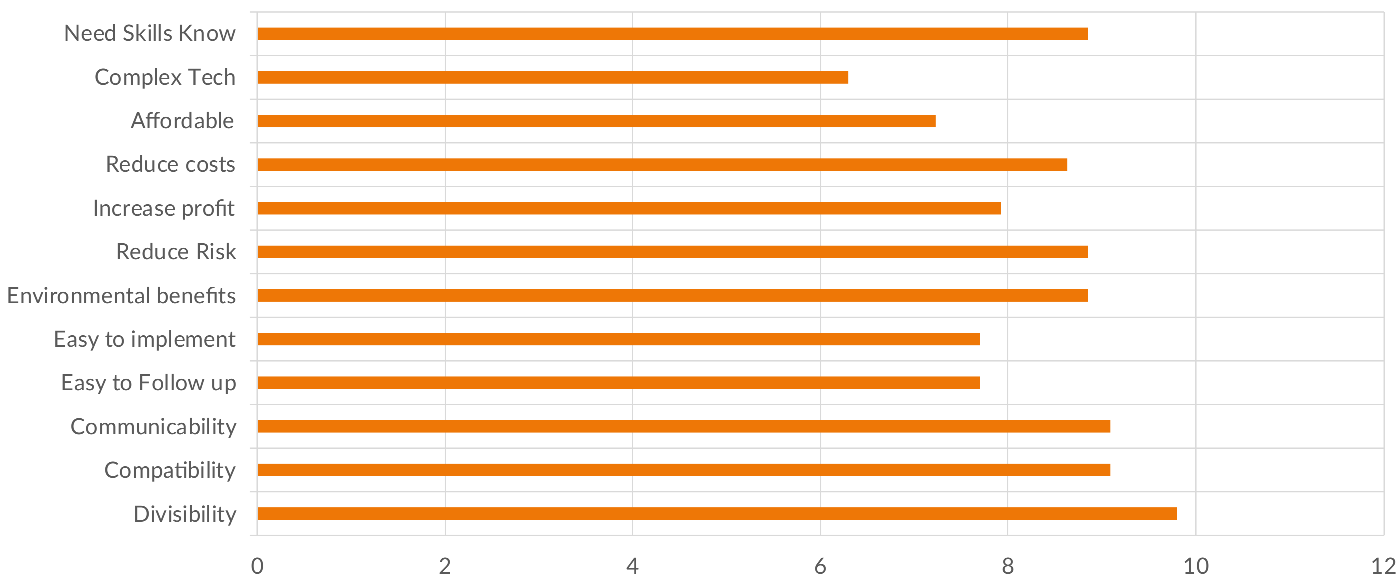
Source: Own elaboration from countries reports (2018).

Table 3. Sample statistics calculated based on respondents (researchers and extension agents) who provide completed answers.

Categories ICARDA-APRP Technologies	Number of complete responses					
	SPC	IF	IPPM	SC	RR	CGH
Strongly agree (6)	34 (40.5%)	18 (21.4%)	30 (35.7%)	17 (20.2%)	20 (23.8%)	21 (25.0%)
Agree (5)	34 (40.5%)	33 (39.3%)	34 (40.5%)	33 (39.3%)	22 (26.2%)	28 (33.3%)
Neither agree nor disagree (4)	9 (10.7%)	6 (7.1%)	9 (10.7%)	13 (15.5%)	18 (21.4%)	15 (17.9%)
Not agree (3)	5 (6.0%)	9 (10.7%)	6 (7.1%)	5 (6.0%)	17 (20.2%)	7 (8.3%)
Strongly disagree (2)	2 (2.4%)	4 (4.8%)	5 (6.0%)	2 (2.4%)	4 (4.8%)	1 (1.2%)
Not sure/not applicable (1)	0 (0.00%)	14 (16.7%)	0 (0.00%)	14 (16.7%)	3 (3.6%)	12 (14.3%)

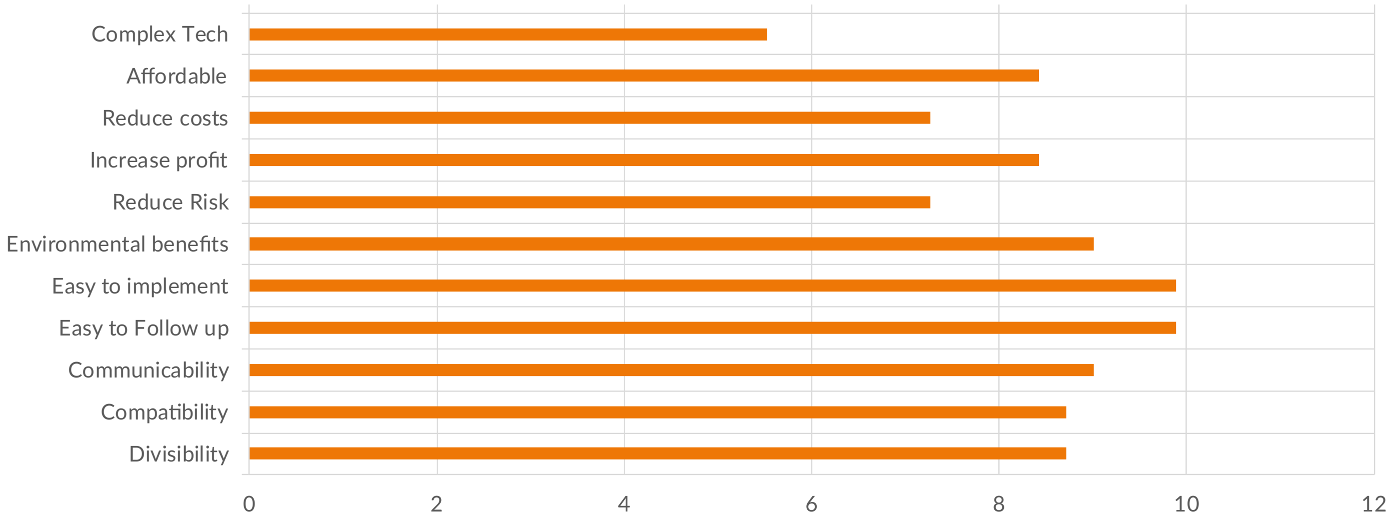
Source: Own elaboration from countries reports (2018).

Figure 1. SPS technology assessment weight between AP countries.



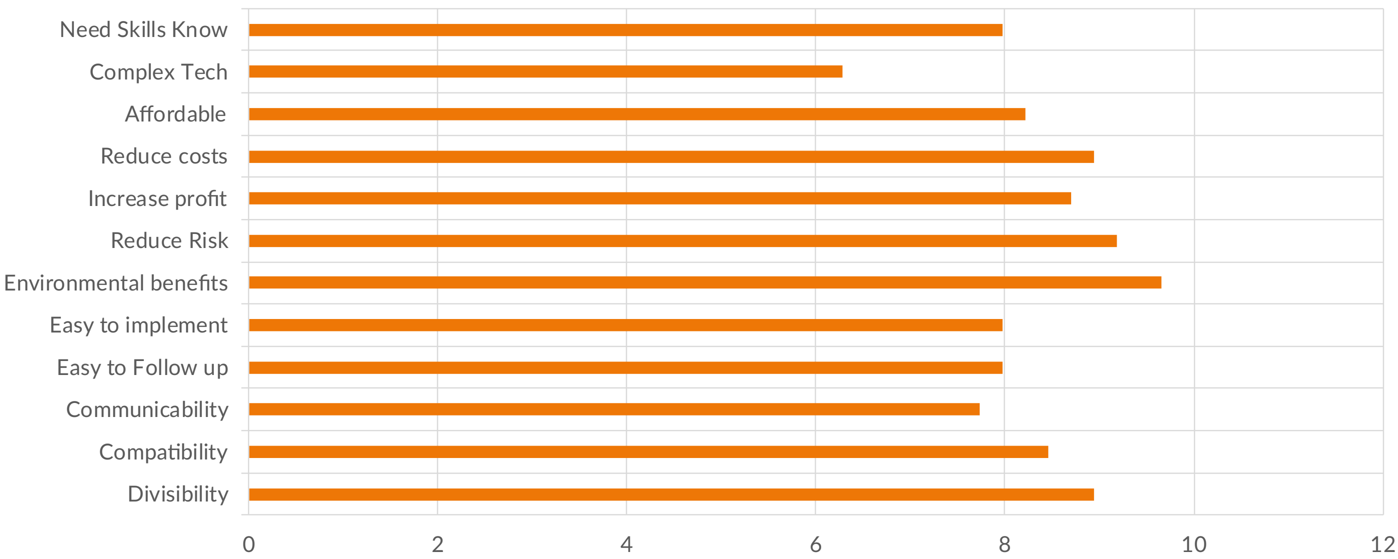
Source: Own elaboration from countries reports (2018).

Figure 2. IF technology assessment weight between AP countries.



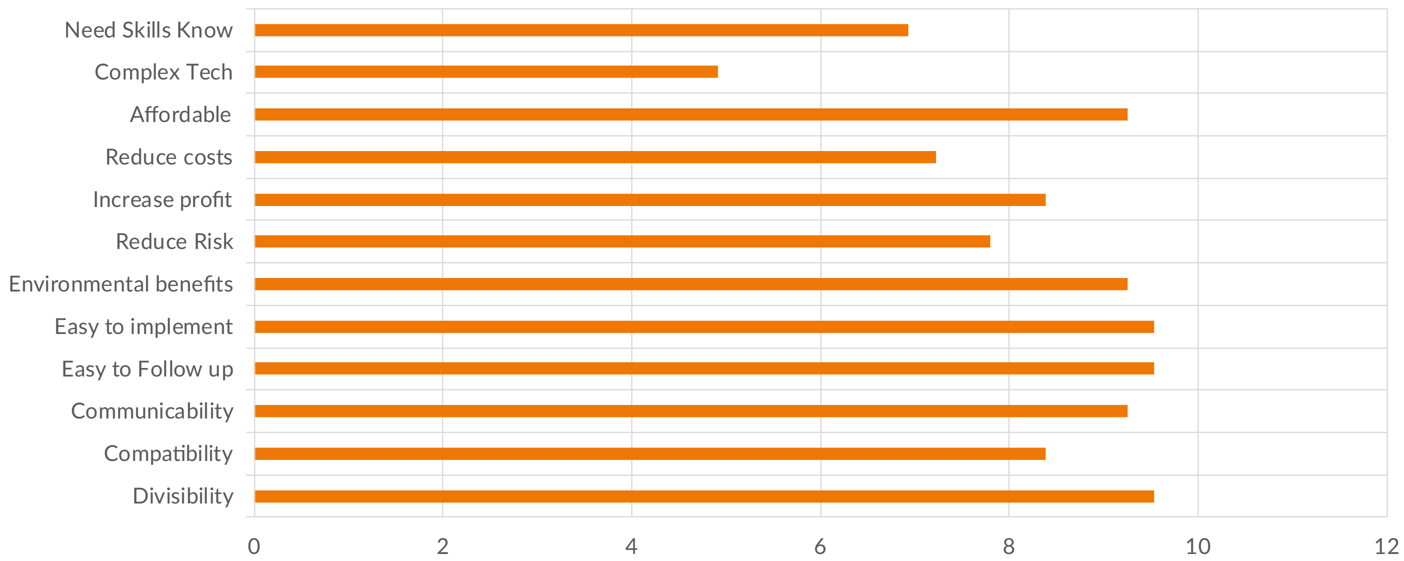
Source: Own elaboration from countries reports (2018).

Figure 3. IPPM technology assessment weight between AP countries.



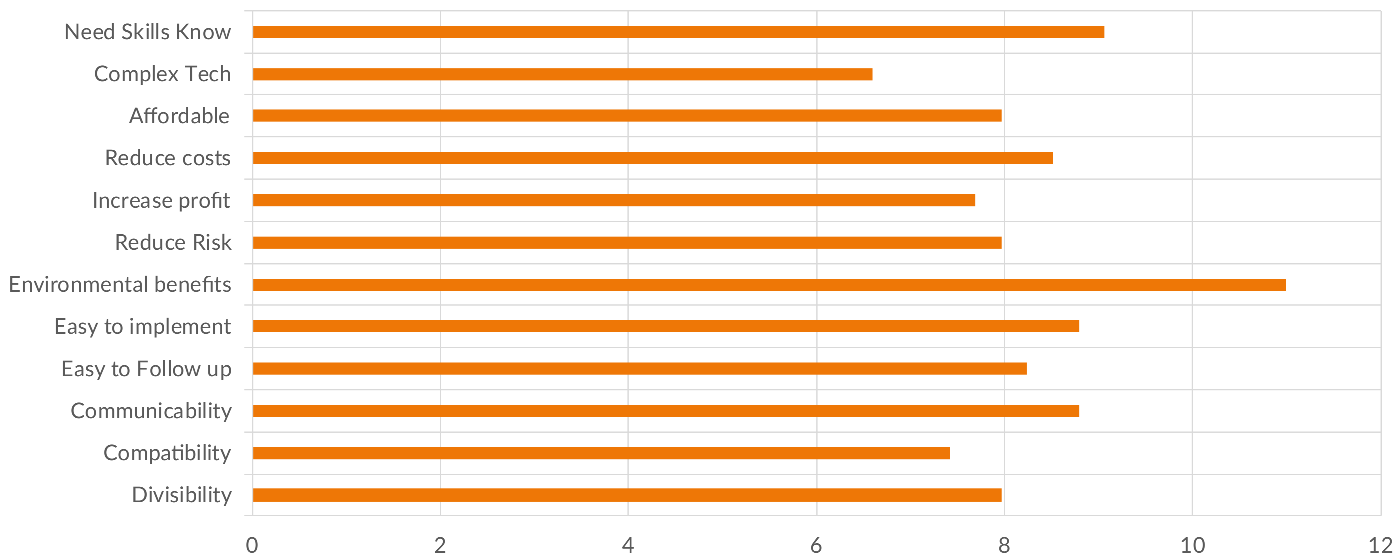
Source: Own elaboration from countries reports (2018).

Figure 4. SC technology assessment weight between AP countries.



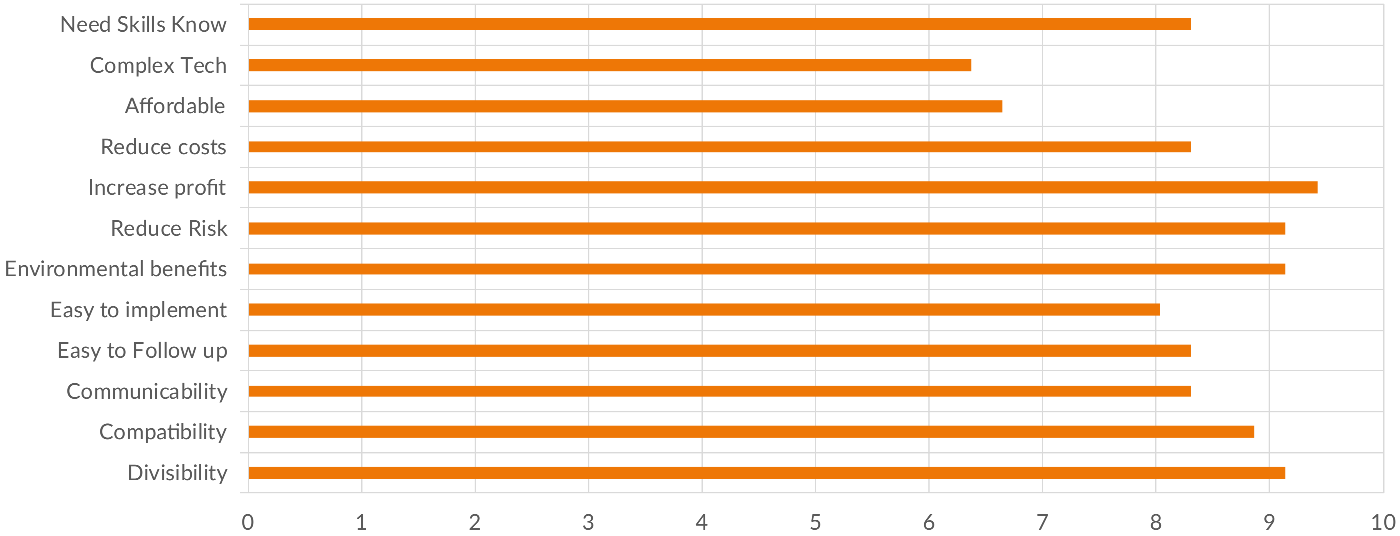
Source: Own elaboration from countries reports (2018).

Figure 5. RR technology assessment weight between AP countries.



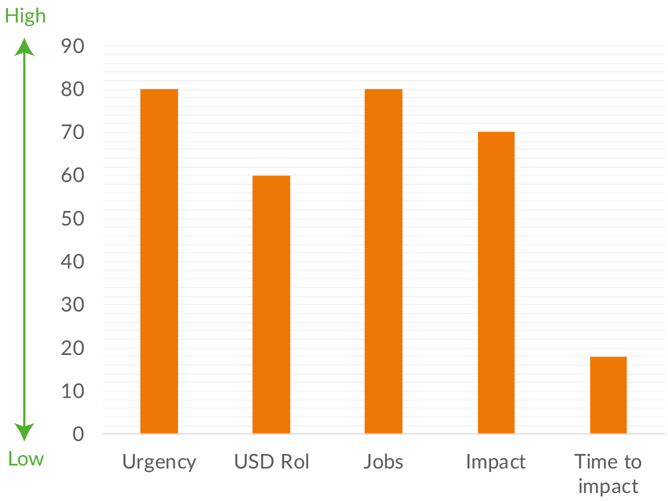
Source: Own elaboration from countries reports (2018).

Figure 6. CGH technology assessment weight between APC countries.



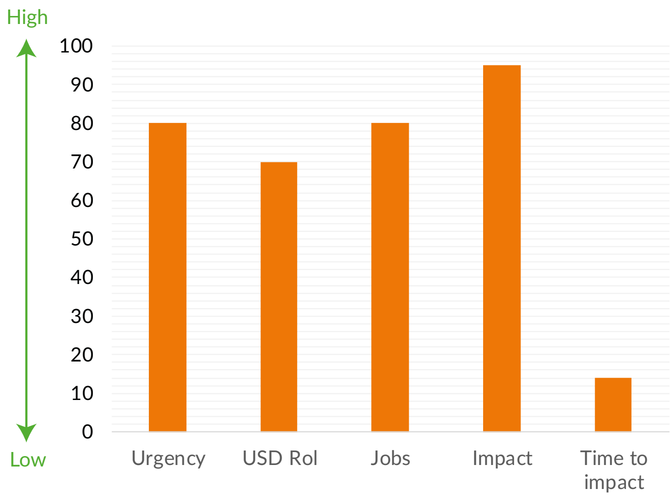
Source: Own elaboration from countries reports (2018).

Figure 7. The road to value: Soilless Production System (SPS) technology assessment.



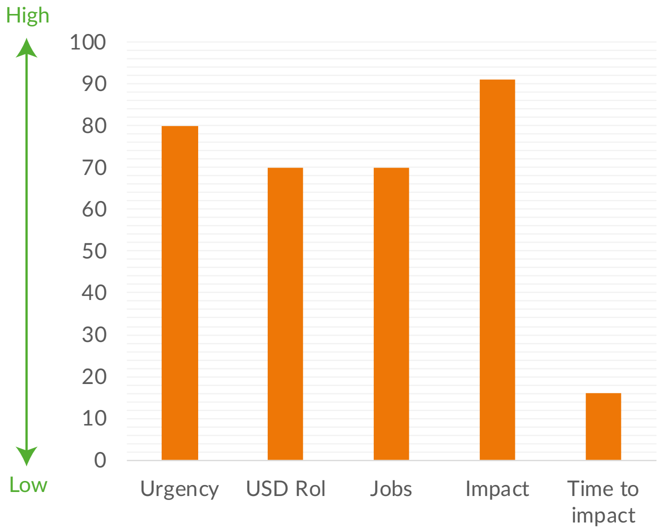
Source: Own elaboration from countries reports (2018).

Figure 8. The road to value: Irrigated Forages (IF) technology assessment.



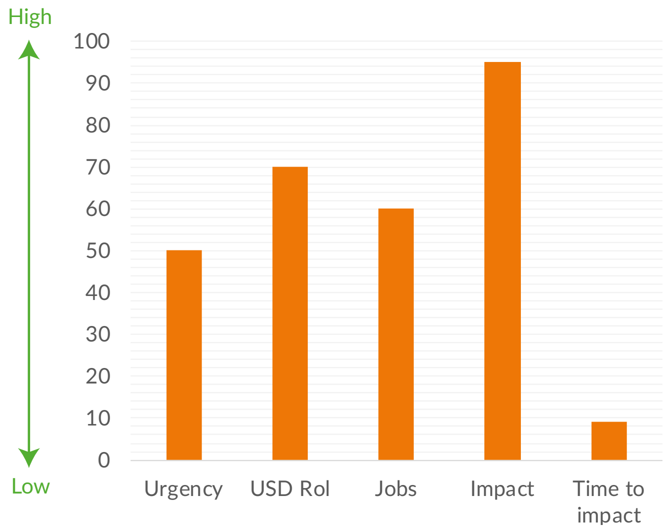
Source: Own elaboration from countries reports (2018).

Figure 9. The road to value: Integrated Production and Protection Management (IPPM) technology assessment.



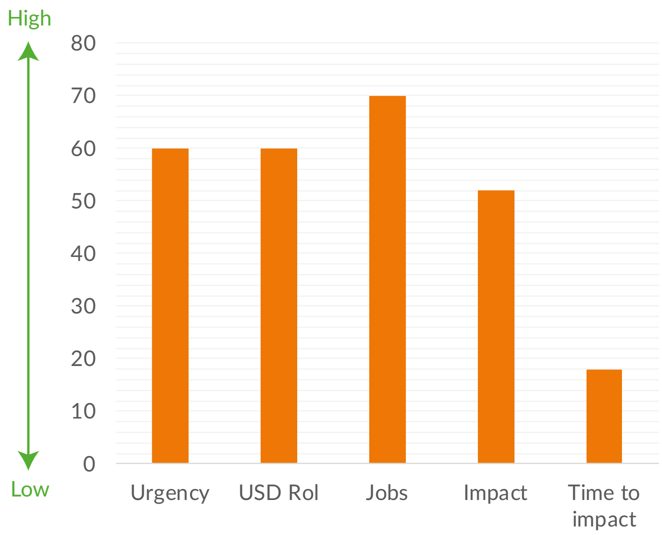
Source: Own elaboration from countries reports (2018).

Figure 10. The road to value: Spineless Cactus (SC) technology assessment.



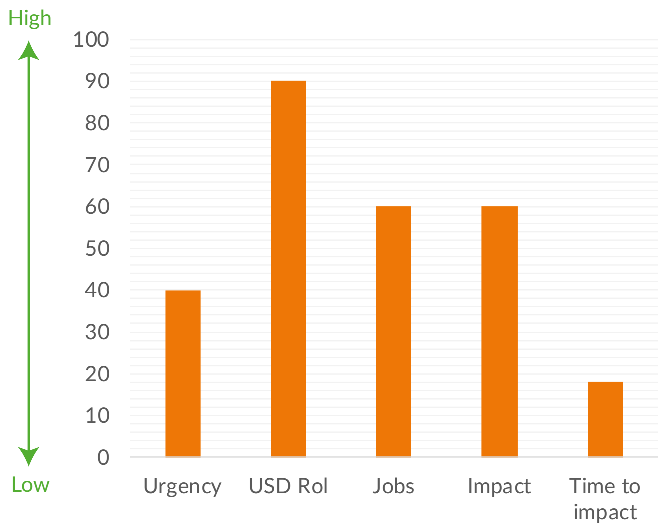
Source: Own elaboration from countries reports (2018).

Figure 11. The road to value: Rangeland Rehabilitation (RR) technology assessment.



Source: Own elaboration from countries reports (2018).

Figure 12. The road to value: Cooling Green House (CGH) technology assessment.



Source: Own elaboration from countries reports (2018).

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