Ukraine

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

BARRIER ANALYSIS AND ENABLING FRAMEWORK REPORT

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This publication is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UN Environment) and the UNEP DTU Partnership (UDP) in collaboration with University of Cape Town. The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP DTU Partnership, UN Environment. We regret any errors or omissions that may have been unwittingly made.

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Foreword

Ukraine plays an active role in international climate change cooperation processes. Being a Party of United Nations Framework Convention on Climate Change and Paris Agreement our country puts significant efforts through its policies and measures to contribute to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

Ukraine has submitted its 1st NDC in 2015. Also, Ukraine has developed its Low Emission Development Strategy up to 2050 in 2017, identifying core policies and measures, which implementation would lead to deep decarbonization of national economy.

However, low carbon development of Ukraine's economy could be obtained only due to wide diffusion and dissemination of modern highly efficient technologies, in particular, for Agriculture, Waste and Water sectors.

For us, the ongoing Technology Needs Assessment project in Ukraine is an excellent opportunity to accelerate environmentally friendly technology transfer that should become the basis for Ukraine to reach the ambitious GHG emission reduction targets and promote low carbon and climate-resilient development of the country. Wherein, Barrier Analysis and Enabling Framework project's phase will recognize in detail the concrete needs in modern technologies to reach ambitious national low carbon development targets for Agriculture, Waste and Water sectors.

Iryna STAVCHUK

Deputy Minister of Energy and

Environment Protection of Ukraine

Executive Summary

This report was prepared as a result of the second stage of the Technology Needs Assessment Project, conducted in Ukraine in late 2019-early 2020. It focuses on defining barriers and enabling framework for the implementation of several selected technologies in the adaptation of agriculture and water sector of Ukraine to the climate change. Agriculture and water are sectors particularly vulnerable to the impact of climate change in Ukraine.

The aim for the Technology Needs Assessment project is to support developing countries and countries with economies in transition to meet their obligations under the convention of the United Nations on Climate Change, bringing contribution to the following:

- The priority of technology needs, which can be used in an environmentally safe technology's package;
- To facilitate an access to and transfer of environmentally sound technologies;
- To identify the transmission-initiated projects and programs;
- To facilitate the implementation of paragraph 4.5 of the convention of the United Nations on Climate Change on the know-how access;
- To define and prioritize technologies, processes and techniques that are consistent with the mitigation of climate change and adaptation in the participating countries are consistent with the goals and priorities of the national development;
- To identify barriers that prevent the primary / preferred acquisition, implementation and dissemination of technology;
- To develop Technology Action Plan to overcome barriers, which will define the scope of activities and a favorable environment that will facilitate the transfer for the adoption of technology and the dissemination of the participating countries.

The prioritized adaptation technologies for the agriculture sector include (i) drip irrigation in the combination with conservation agriculture practices; (ii) agroforestry practices (shelterbelt reconstruction); (iii) integrated pest and disease management (biodegradable mulch film).

The prioritized adaptation technologies for the water sector include (i) climate-smart irrigation; (ii) drought risk assessment and mapping; (iii) flood risk assessment and mapping.

These technologies were identified and prioritized through a participatory consultation process of sectoral stakeholders during the first stage of Technology Need's Assessment Project conducted in 2019.

The second stage aimed to develop the Barrier Analysis and Enabling Framework report following the technologies' characteristics described in the stage earlier.

The document was developed considering the guidelines provided in the UNEP DTU Partnership, the Second Edition of Overcoming Barriers to the Transfer and Diffusion of Climate Technologies guidebook (Nygaard, I. & Hansen, U. E., 2015). The work was focused on answering two issues: to identify barriers in terms of diffusion of each selected technology; and outline the modality of addressing barriers within an enabling framework.

To reach this, the LPA method, developing Problem, and Objectives Trees, as well as Market mapping, was applied by the national teams in BAEF.

The activities for BAEF developing were implemented in cooperation with the Ministry of energy and environment protection of Ukraine, research institutions, business, non-governmental organizations and other. The representatives of the leading state institutions, public organizations, and businesses were invited to join the TNA national team in adaptation, divided into two working groups of the agriculture and water sectors. Considering the different levels of gender influence in the process of technology implementation, the working groups included fair involvement of women, and the entire process of BEAF report preparation was gender balanced.

To identify barriers, desktop research was conducted by national consultants and working group meetings to elaborate the long and shortlists of barriers with further screening. The preliminary targets for each technology's transfer and diffusion were established on the basis of the analysis of environmental and market capacity per sector as well as following the gender assessment. Considering the main findings obtained in the result of the sectoral analysis, expert discussion, and overviewing the existent relevant national legislation and regulation, the barrier analysis was conducted applying the cause relationship method visualized as a Problem Trees.

At the second stage, the enabling measures were identified in the process of consultations with experts based on the next input parameters:

- Measurable and realistic. Realistic measures should be politically, mentally, culturally, and technologically relevant and easily integrated into the current living conditions in the country.
- At least the initial level of the legislative framework and institutional capacity have been already created for the implementation and conduction of the suggested measures.
- Time frame. The measures can be implemented in short-term prospects.

The enabling measures were developed per each technology and presented applying the Objective Trees. The list of the essential barriers and response enabling measures are summarized in Table 1.

The categories of different barrier have the different level of impact on technology transfer and diffusion. However, some of the identified barriers have crucial or several important impacts on all prioritized technologies. It was noted that the legal and regulatory barriers a common for all prioritized technology. Even more, the absence of the nationally defined climate change policy, lack of effective land market's mechanisms, and mechanisms of financial support are barriers that significantly impact the development of all technologies in both sectors. The linkages between them were developed and presented for the relevant sectors.

Enabling framework refers to the existing enabling measures along with those, that should be developed and accelerated to overcome the mentioned barriers. Some of the frameworks are applicable for all technologies. Additionally, the linkages between stakeholders and objectives towards strengthening the enabling framework were marked on the market maps.

Finally, creating the full prospect picture to technology's diffusion, the market mapping was performed and presented based on the analysis of the causal relationship among barriers, enabling measures, and stakeholders involved in the process.

Table 1. Identified nonfinancial barriers and overcoming measures for technology transfer and diffusion in agriculture and water sectors.

AGRICULTURAL TECHNOLOGIES					
Drip irrigation in the combination with conservation agriculture practices		Agroforestry practices		Integrated Pest and Disease Management	
Identified Barriers	**Proposed Measures**	**Identified Barriers**	**Proposed Measures**	**Identified Barriers**	**Proposed Measures**
The absence of an effective agricultural land market	1. The abolition of the moratorium on the land for sale scheduled for October 2020 2. The clear and transparent mechanism for land market liberalization developed and incorporated into the law.	The unclear legislative mechanism of shelterbelt management	1. Improving land management under the shelterbelt[1]; 2. The incorporation of the rule of shelterbelt planting and maintain 3. . Developing the lease agreements of shelterbelt for the different type of consumers.	Low priority of CC adaptation measures	1. IPM including the BMF production should be incorporated in the CC mitigation and adaptation strategy. 2. Conducting the economic assessment of the climate change impacts. 3. Developing the national environmental monitoring system.
Poor conditions of irrigation infrastructure	1. Financial support from the international donor organizations such as the World Bank and EBRR. 2. Forming the revolving of funds for the irrigation infrastructure facilitation on the level of united village communities.	Corruption caused by SPR	1.Increasing the public control role in village communities to define the shelterbelt 2.The automation of the process for issuing permits to forestry tickets 3.Developing the permanent monitoring	Low interest to innovative sustainable business models	1. Conducting the national studies of cost-benefit analysis that compares different pest control technologies with a focus on the ecosystem 2. Developing enhanced value-added chain business models for crops with a high amount

[1] «On Amendments to Some Legislative Acts of Ukraine on Collective Land Ownership, Improvement of Land Use Rules in Agricultural Land Lands, Prevention of Raiding and Encouragement of Irrigation in Ukraine» https://zakon.rada.gov.ua/laws/main/2498-VIII%20target=

	3. Developing the legal regulation mechanisms for the transfer the ownership rights on the objects of the irrigation infrastructure to long-term free use for water users' organizations.		system of the shelterbelt conditions 4. The creation of the local inspections to define activities for shelterbelt maintenance.		of starch as a main feedstock of BMF production.
Insufficient skilled manpower	1. Facilitating the professional network among farmers 2. Moving towards the decreasing the wages disparity 3. Developing the relevant courses of in-service education 4. Launching summer schools	The lack of state financial supporting mechanisms	1. Incorporation to the global system of climate subventions 2. Developing the market of climate action incentive payments 3. Optimizing an approach for redistributing the budget of money such as the "ecological" funds.	The inefficient capacity of Extension services (ES)	1. Providing ES with guides on the technology implementation by oblast 2. Increasing ES capacities through the creation of the common database of the available machinery and equipment and etc.
Low level of awareness	1. Developing the Strategy on mitigation and adaptation to CC 2. The incorporation of the CC indicators into the national accounts 3. Developing and integrating issues related to climate change into the scope of extension services	Shortage in the supply of planting material	1. Local public companies equipped to plant shelterbelts and wood residue recycling 2. Increasing the amounts of container nurseries to produce ball-rooted planting stock 3. State nursery's technical modernization	Absence of regulation on plastic film application	1. Penalties for the use of certain types of plastic from 2022. Draft law № 2051-1; 2. Prohibition on plastic up to 50 microns thick and oxo folding plastic.

Lack of state financial supporting mechanisms	1. The optimization the approach to the redistributing the budget money such as the "ecological" funds; 2. Developing the mechanism to attract the international "climate" or "green" payments under the CA development.	Low priority of CC adaptation measures on the government level	1. Developing the sub-section for scaling up the agroforestry practice 2. Conducting a study of a quantitative assessment of CC risks on agroforestry 3. The economic assessment of CC impacts on soils, water reservoirs, and biodiversity	Lack of understanding of the significant benefits of using BMF	1. The creation (and maintenance) of the community of practices for this specific technology would be a significant contribution in its promotion; 2. Launching the exchange farm-to-farm visit training with the best practice demonstration.
Relatively high investment cost	1. Increasing capacity of the Partial Agricultural Credit Guarantee Fund to decrease the loan ratio 2. The extension of the state program for partly compensation of purchase expenses on agriculture types of machinery and equipment by the irrigation equipment.	Lack of the capacity to conduct the shelterbelt inventory	1. The extension of the remote sensing application for shelterbelt inventory; 2. Launching the practical training for the professionals; 3. The modification of the academic study programs.	Lack of raw materials and technologies for BMF to arrange domestic production	1. Cross-subsidization under the investments into the biotechnology 2. Subsides from the Ukrainian State Fund of Financial Support[2] 3. Decreasing the production cost through the clustering of farming units 4. Decreasing the loan ratio 5. The extension of the state program for partly compensation of purchase expenses on
Long-term pay-off period	1. The optimization of the production cycle;	Lack of capacity to develop the PPD	1. The creation of an electronic catalog of seedling and nurseries	Lack of manufactures, BMF producers	

[2] https://udf.gov.ua/

	2. Cross-subsidization and production diversification 3. Agro insurance.		including climate resilience and economically efficient species 2. Launching professional training		agriculture types of machinery 6. Increasing penalties for the not proper plastic utilization
Insufficient knowledge	1.The extension of the master program in agronomy 2.Involving farmers and leading experts as lecturers 3. Strong cooperation between farmers and academy	The absence of clear guidance for shelterbelt management	1. The elaboration of the best agroforestry practice guideline; 2. Developing the step-by-step guideline of shelterbelt inventory for farmers and rural communities.	Competitively high price of BMF	1. The optimization of the production cycle 2. The extension of the advertising company 3. Improving the marketing strategy; 4. Business models optimization 5. Increasing penalties for improper plastic utilization
The low priority of CC adaptation measures	1. The acceptance of the draft Strategy Climate Change mitigation and adaptation strategy of agriculture; 2. Conducting a study of a quantitative assessment of climate change risks by sub-sector and regions on agriculture	Limited knowledge on technology implementation	1. The development and popularization of the educational web-channel for technology promotion; 2. Creating the open base of the best practices and success stories.		
WATER SECTOR TECHNOLOGIES					
Climate-smart irrigation		**Drought risk assessment and mapping**		**Flood risk assessment and mapping**	
Barriers	**Measures**	**Barriers**	**Measures**	**Barriers**	**Measures**

The inconsistency of property rights	1. The creation of water users' associations within the basin 2. The development of mechanisms for state support for the acquisition of irrigation machinery and elements of the climate-smart irrigation system by farmers; 3. The transmission of local level irrigation networks as part of the decentralization process to the local governments, and credit or investment resources can be mobilized there by local government efforts.	Lack of state support of hydrometeorological monitoring	Increasing of state support of hydrometeorological monitoring, search for investment, financial credits, funding.	Lack of state support of hydrometeorological monitoring;	Increasing of state support of hydrometeorological monitoring, search for investment, financial credits, funding.
Tariff for water for irrigation insufficient for renewal of capital assets	The tariff for irrigation should cover not only the cost of electricity, but also the cost of innovation and development expenditures.	Lack of long-term satellite, meteorological and hydrological data sets	1. Joining the NMHS of Ukraine to the EUMETNET 2. Creation of satellite, meteorological and hydrological data base	Lack of long-term satellite, meteorological and hydrological data sets	To strengthen collaboration with EFAS.
The limited availability of local suppliers of equipment and services	1. The development of complex national target economic program stimulating machinery output;	Lack of experts for drought assessment and mapping	The training of experts for drought assessment and mapping.	Lack of experts for modelling and forecasting of floods	1. The education of experts for modelling and forecasting of floods

	2. The cooperation of machinery producers with IT companies; 3. The establishment of domestic production facilities				2. Preparing of individual training plans 3. Collaboration with EFAS, Delft company (NL) and other to training of personal 4. SESU needs to reform job payment system (increasing of monthly payment)
Low awareness on the benefits of technology	1. The study of international experience 2. Awareness raising campaigns that could be conducted by equipment sellers 3. The inclusion of information on climate-smart irrigation technology into the curricula of universities; 4. Training programs for the representatives of agri companies.	High financial costs	The implementation of the WMO service delivery strategy. Search for financial support from donors and funds.	High financial costs	1. The implementation of the WMO service delivery strategy 2. Search for financial support from donors and funds.
Obsolete and physically missing infrastructure for irrigation	1. The renovation of infrastructure for irrigation by the members of water users' associations;	Expensive hardware components of technology	Search for collaboration with developers and providers of technical aid possibilities	Expensive hardware components of technology	Collaboration with EFAS, Delft company (NL) to access to innovative technologies.

	2. The modernization of irrigation networks inside one region				
Lack of detailed assessment of water available for irrigation	Analysis and modelling of available rivers is needed, as well as forecasts of how the droughts will affect the availability of water in rivers in Ukraine.	Expensive licenses for software components, detailed topography maps	Purchase annual licenses, creating conditions for sharing of software, maps.	Expensive licenses for software components, detailed topographic maps.	Access the financial support from donors and funds.
The unauthorized and untreated extraction of water for irrigation from artesian fields	Thorough control of water withdrawal by controlling bodies.	Imperfect legislative and regulatory framework for technology implementa tion	1.Developing the legislative and regulatory framework for technology implementation. 2. The adoption of the Law "Sustainable development strategy of Ukraine by 2030". 3. The creation of the legal framework for satellite monitoring technologies implementation.	Imperfect legislative and regulatory framework for technology implementation	1. Developing of legislative and regulatory framework for technology implementation: 1. Developing of national regulatory framework for creation of flood risk management plan (FRMP), and preliminary flood risks assessment. 2. The creation of the legal framework for satellite monitoring technologies implementation.
No legislation regulating climate-smart irrigation technology	The development of respective legislation by the means of extending the existing Strategy of irrigation and dewatering in Ukraine until 2030.	The lack of awareness about benefits of technology	Wide awareness campaigns carried out by the authorities, the media and NGOs.	Lack of awareness about benefits of technology	Wide awareness campaigns carried out by the authorities, the media and NGOs.

		Inefficient insurance system: ignorance of the benefits of technology	1. Powerful awareness campaign for stakeholders and insurance companies should be undertaken 2.The implementation of bonus-malus-system of insurance.	Inefficient insurance system: ignorance of the benefits of technology	1.Powerful awareness campaign for stakeholders and insurance companies should be undertaken. 2. The implementation of flood zone on the basis of insurance policy 3.To amend the Law of Ukraine "On Insurance" and to introduce a mandatory flood insurance system.
The high cost of technology	Special funding program anticipating the reimbursement of interest rate for loans obtained from commercial banks				
The high cost of capital	Long-term soft loans through cooperation with international financial institutions				
Difficulties with access to capital	Import tax exemption by means of assigning codes to the equipment for Climate-Smart Irrigation within Ukrainian Industry Classification System.				

CONTENT

List of Acronyms

ADPC	Agricultural and Domestic Production Costs
AVC	Amalgamated Village Communities
BA&EF	Barrier Analysis and Enabling Framework
BMF	Biodegradable Mulch Film
CA	Conservation Agriculture
CC	Climate Change
CMU	Cabinet of Ministers of Ukraine
CO2	Carbon dioxide
CSI	Climate-Smart Irrigation
DBE&DWQ	National Dnieper Basin Environmental and Drinking Water Quality Program
DICA	Drip irrigation with conservation agriculture practices
DTU	Technical University of Denmark
EBRD	European Bank of Reconstruction and Development
EIA	Environmental impact assessment
ESRI	Environmental Systems Research Institute
FEWS	Flood Early Warning Systems
FRMP	Flood risk management plan
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographical Information System
IBRD	The International Bank for Reconstruction and Development
IDO	International donor organizations
M&A	Mitigation and adaptation
MDETA	Ministry for Development of Economy, Trade and Agriculture
MEEP	Ministry of Energy and Environment Protection of Ukraine
NAP	National action plan
NBU	National Bank of Ukraine
NDVI	Normalized Difference Vegetation Index
NFIP	National Flood Insurance Program
NLDCs	Neutral Levels of Land Degradation
NMHS	National Meteorological and Hydrological Services
PFRA	Preliminary flood risks assessment
PML	Plastic Mulch Layer
PPD	Planting Project Documents
R&D	Research and development
SDI	Subsurface drip irrigation
SESU	State Emergency Service of Ukraine
SPEI	Standardized Precipitation-Evapotranspiration Index
SPI	Standardized Precipitation Index
SPM	Shelterbelt planting and maintain
SPR	Shelterbelt protection regulation
WMO	World Meteorological Organization

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Chapter 1. Agriculture sector

1.1. Preliminary targets for technology transfer and diffusion

The export of agricultural products from Ukraine in 2018 amounted to $18.8 billion. Last year, agro-industrial products accounted for 39.8% of total exports from Ukraine and retained leadership in its commodity structure. The key products of Ukrainian agrarian exports in 2018 were grain crops, oil, seeds of oil-seed crops, meat and offal, which account for about 81% of exports in monetary terms. Crop production increased by 10.7% and livestock production - by 0.2%. In general, Ukraine has become one of the five largest suppliers of agricultural products to the EU. Nowadays, Ukraine is one of the main world's exporters of agricultural products. In five years, the profitability of the agrarian sector has increased from 20.5% to 31.6%, and this attracts new investments, including those from abroad.

In spite of stable growth of agricultural production in Ukraine, the policy framework does not prioritize the development of sector resilience to climate change, particularly in terms of increasing its adaptation potential. There is no supporting state regulation, or financial mechanisms to stimulate actors involved in agriculture to provide adaptation measures and increase sectoral resilience

In The first stage of the TNA project, the next technologies were prioritized for CC adaptation of the agriculture sector: (i) Drip irrigation in combination with conservation agriculture practices; (ii) Agroforestry practices (shelterbelt reconstruction); (iii) Integrated Pest and Disease Management (biodegradable mulch film).

The preliminary targets for technology transfer and diffusion are caused by the set of forcing circumstances and limits. On the permanent basis, they are specified by the environmental conditions, national regulation, and maximum of the business capacity to implement to proposed technologies. Moreover, further expectations which refer to international market's developing priority, trading commitments, restrictions and the capacity of the banking and forcing circumstance's financial sector might define the preliminary targets for technology transfer as well. Finally, there is a set of fundamental natural, historical, cultural limitations that affected the potential of technology development.

Limits and forcing outlines for technology transfer and diffusion were analyzed based on reviewing the available publications and data, discussed with the relevant experts, and then briefly described per each technology. Tentative targets for technology transfer and diffusion were proposed, correspondingly.

Drip irrigation, in combination with conservation agriculture practices, is a complex technology combination of two in one. In our case, technology was classified as a Capital goods due to wide demand from the side of farmers, high capital cost and mandatory state contribution to develop the common infrastructure under technology implementation. Technology dissemination depends on the double circumstances refer to the conservation agriculture and climate-smart irrigation application. This fact defines the outlines of technology's market liquidity and its potential being scale-up (Table 1.1.).

Table 1.1. Outlines to define the preliminary targets for technology transfer and diffusion: Drip irrigation, in combination with conservation agriculture practices

Outlines	Capacity
Natural resource availability	Available. Only 3% annual intake of water resource for the agricultural sector has been used from the total

	volume of renewable water resources. There is no other limitation for natural resources for the technology implementation.
Business potential	There is 25% of farms (12K farms) which processed around 31% (10,5 mln. ha) of arable lands which can apply conservation agriculture. About 20 mln hectares of arable lands were under the irrigation on the area of modern Ukraine, by 1990.
Natural hazard and disasters	The number of days with high air temperatures (more than 30 °C) has increased; frequency of days with maximum temperatures is higher than 35 and 40 °C almost doubled; annual sum of active temperatures has increased by 200-400 ºC; the emergence of a non-typical thermal zone with annual sum of active temperature amount is higher than 3400ºC in the South.
National Regulation	"Irrigation and drainage strategy in Ukraine by 2030"; The Law of Ukraine “On Environmental Impact Assessment”; The Law of Ukraine “On amelioration of lands”. Order №722/2019 On Sustainable Development Goals for Ukraine for the period till 2030.
Aligning with international markets or trading commitments	Climate-smart agriculture and the Sustainable Development Goals: Mapping interlinkages, synergies and trade-offs and guidelines for integrated implementation (FAO, 2019).

Following "Irrigation and drainage strategy in Ukraine by 2030", the need to restore irrigation is on the 1.2 million hectares in the areas around reservoirs, major trunk channels with available pumping stations and other interfirm systems by scaling up to the area of 1.7 million ha. It also stimulates the development of irrigation technologies and the production of agricultural equipment, in particular, by providing compensation to farmers for purchasing national production equipment.

The generalization of the conducted scientific researches allows us to make a general conclusion that, under favorable conditions of soil environment, its tillage can be reduced to a minimum or it can even completely abandoned. Scholars contend that of 32 million hectares of arable land in Ukraine, the minimization of cultivation is practically impossible in 6.4 million hectares, zonal technologies with separate elements of minimization should be applied in 5.1 million hectares, the minimum cultivation is proposed in 13,01 million hectares, and *no-till can be applied* in *5.49 million hectares.*

The technology’s adaptation potential to climate change can be demonstrated by the following:
- sowing crops in the most suitable agricultural period;
- preventing crop losses due to dust storms and heavy rainfall;
- the improvement of the subsurface layer thermoregulation and moisture retention during heatwave and evaporation;
- crop rotation optimization under shifting sowing dates;
- the conservation of biodiversity and prevention of desertification.
- to reduce and optimize water consumption;
- contributes to the conservation of biodiversity and soil micro- and mesofauna enrichment earthworms.

Currently, the main driving force of technology's diffusion is the increasing interest of agriculture producers to this technology.

Tentatively, the recommended drip irrigation in combination with conservation agricultural practices scaled up to around 15% (5,0 mln. ha) of arable lands in Ukraine which processed the 19% of the farms (7 K farms). The geographical coverage is zones with a moisture deficit of 300 mm or more, the steppe zone of Ukraine (Kherson, Mykolaiv, Odesa, Kirovograd, Zaporizhia, Donetsk and partially Kharkiv and Dnepropetrovsk oblast).

Agroforestry practices could be classified as Other non-market goods, which mainly means that technology diffusion highly depends on the relevant state policy. However, the agriculture producers which are facing the increasing natural hazards are highly interested in using field protection shelterbelts to defend the soil against erosion and increase in land productivity. Moreover, climate orientated agroforestry practice is the way to increase their economic diversification. Moreover, the local village communities - principal shelterbelt owners - demonstrate their interest in developing agroforestry practices. Following these and other outlines, preliminary targets for technology transfer and dissemination were identified (Table 1.2.).

Table 1.2. Outlines to define preliminary targets for technology transfer and diffusion: Agroforestry practices

Outlines	Capacity
Natural resource availability	Various agroforestry practices can be developed for all agro-climatic zones of Ukraine, especially forest-steppe and steppe zones (TNA A, 2019)[3]. Especially, it is noticeable in the conditions of the arid climate. Moreover, the developing agroforestry varies depending on the conditions of growth and the state of trees, their distribution in the catchment area, the topography of the area, and the degree of erosion, the steepness of slopes, as well as the economic conditions of the region. Finally, the agroforestry technology selection depends on the wind speeds typical for the area.
Business potential	There is no relevant data to identify the business potential for technology implementation. Due to official information, there are about 440K hectares of agricultural land that can be covered by the shelterbelt. Shelterbelt inventory has not been performed since the middle of sixty, last century.
Natural hazard and disasters	The total area of agricultural land affected by water and wind erosion is more than 16 million hectares, of which about 14 million hectares are arable land. Annual loss due to erosion processes reaches almost 600 million tons of humus. It increases the dust storm's appearances.

[3]Technology need assessment report. Adaptation. 2019. https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2019/09/final-ukraine-tna-adaptation-report.pdf

National Regulation	The Forest Code of Ukraine, Land Code of Ukraine; The Law of Ukraine "On Environmental Protection"; The Law of Ukraine "On Local Self-Government in Ukraine"; The Law of Ukraine "On Local State Administrations"; The Law of Ukraine "On Land Protection"; The Law of Ukraine "On Nature Reserve Fund of Ukraine"; The Law of Ukraine "On the ecological network of Ukraine"; The Concept of Reform and Development of Forestry, Resolution of the Cabinet of Ministers of 19.19.1996 No. 1147 (amended) "On the approval of the list of activities related to environmental protection measures
Aligning with international markets or trading commitments	The agroforestry practice in Ukraine might be an attractive investment on the global carbon market due to its carbon sequestration capacity

Climate change adaptation potential of agroforestry practice:
- The preservation of soil quality and increase in its fertility by preventing erosion;
- The prevention of crop losses caused by dust storms and heavy rainfall;
- To reduce the climate change impact on the cultivated land by the means of snow retention, subsurface layer thermoregulation, and moisture retention during heatstroke and dehydration;
- The preservation of agroeconomic productivity through biodiversity conservation practices.

Climate change mitigation co-benefits of agroforestry practice:
- by reducing CO2 emissions into the atmosphere as a result of increasing stock of productive herbage wood;
- carbon sequestration;
- reducing the emissions of greenhouse gas by increasing the use of biomass fuels.

Preliminary targets for agroforestry technology transfer and diffusion are counted by the existing - 440 thousand hectares of agricultural land allocated for shelterbelts, 18,200 thousand km of railways; the expansion of shelterbelts on the area of 1.2 million hectares, anti-erosion - 1.6 million hectares.

Potential users are medium and large-scale farms (from 100 hectares in processing), nearly 4,200 farms, Ukrzaliznytsia, oblast departments of State Agency of Automobile Roads of Ukraine.

In the next sub-chapters, barriers identified and enabling measures provided with regard to the reach proposed targets.

<u>Integrated Pest and Disease Management (biodegradable mulch film)</u> is classified as *Consumer Goods.* The implementation of this technology allows to increase the resilience of livelihoods of rural communities, which are the most vulnerable to the impact of climate change for population, and it is in line with a state policy for food and economic security. To a large extent, food security is formed by households, as defined by the Decree of the Cabinet of Ministers of Ukraine of the 5th December, 2007 No. 1379 on approval of the Methodology for determining the key indicators of food security. The level of economic security is approved by the order of the Ministry of Economy of Ukraine No. 60 of 02.02.2007. Food security is defined by the National Security Strategy of Ukraine as one of the main areas of state policy in the economic sphere.

Preliminary targets for BMF technology transfer and diffusion might be defined by the next indicators:

1. Increasing the vegetable production on the level 2009[4] *without changing in the use of land: tomatoes up to 14%; pumpkin production up to 8%, onion - 12%, pepper - up to 6%; chilly paper - up to 2%.*
2. The BMF can be applied at least in the areas of 270 thousand hectares ha in each agro-climatic zone in Ukraine for vegetable production and replaced existent plastic greenhouse production.

It is important to take a note, that the preliminary target for technology transfer is guided by the principles of gender equality and women's empowerment. Gender inequalities and specific roles that women and men play, as well as their unique needs, vulnerabilities, and sources of livelihoods, must be considered in adaptation strategy.

In general terms, women and men experience the climate change differently, and gender inequalities (which can encompass economic disparities, differences in access to productive resources, different levels of education, and cultural norms, for instance) affect their abilities to successfully adapt. At the same time, women's contributions to find long-term solutions to climate change are often unrecognized, in part because women are often excluded from formal decision-making at production and national levels.

Technology transfer and diffusion through the gender focus in agriculture.
It is worth noting, that the preliminary target for technology transfer is guided by the principles of gender equality and women's empowerment. Gender inequalities, and the specific roles that women and men play, as well as their unique needs, vulnerabilities, and sources of livelihoods, have been taken into consideration in their potential to technology diffusion.

In general terms, women and men experience the climate change differently, and gender inequalities (which can encompass economic disparities, differences in access to productive resources, different levels of education, and cultural norms, for instance) affect their abilities to successfully adapt. At the same time, women's contributions to find long-term solutions to climate change are often unrecognized, in part because women are often excluded from formal decision-making at production and national levels (Figure 1.1).

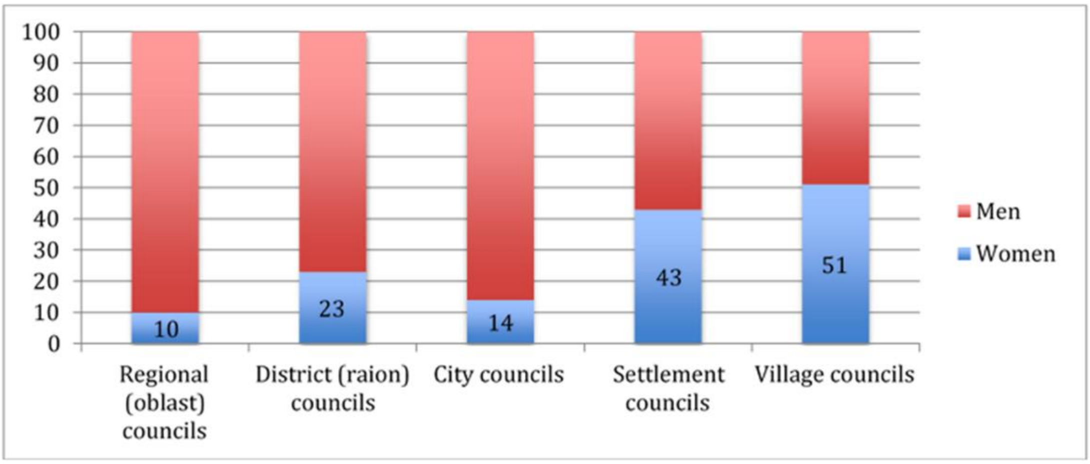

Figure 1.1. Women's Representation on Councils at Differing Levels, 2014 (%)
Source: (Alekseyenko, 2014)

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[4] There were not needed in export in tomatoes, pepper, and pumpkin until 2009. The vegetable production has been covered in-country demand.

With respect to the degree that women representing rural constituents occupy positions in legislative office, it is significant that the proportion of women in governance decreases with the level of authority, means that women are better represented at the most local levels of decision-making. At the national level, the number of women in Verkhovna Rada (national parliament) of Ukraine has increased incrementally since independence, but the pace is so slow that it could take decades to reach the level of 30 percent representation by women, which is the proportion thought to be the minimal "critical mass" to have an impact on decision-making. In the first convocation of the Verkhovna Rada (1991-1994), only three percent of deputies were women; by the eight convocations (2014 to the present), women have reached 12 percent in 2017. (ICPS, 2017)

After the 2015 local elections, women gained around 15 percent of seats on regional (oblast level) councils, but there is considerable regional variation, with only one region achieving 21 percent female council members and several with 11 percent or fewer women- less than the proportion of women in the national parliament (ibid., p. 14). Women were best represented in village councils, where they were over half of the council members. (Figure 1.1)

Assessing rural women's empowerment and participation in decision-making in the household or concerning agricultural practices is complicated as women's role may differ depending on the household type and the decision being considered. Rural women report that they more often make decisions about how land for growing agricultural products is used when they are not living with a husband or partner.

Table 1.3. Women's responses to the question "Who makes the final decision about the use of land for agricultural products that are grown for sale?"

	Living with husband or partner	Not living with husband or partner
Your husband or other male relative	48%	32%
You	34%	41%
Your female relative	5%	15%

Source: (Volosevych, 2015)

Still, women participation in such decision-making is high even when they are married or partnered (Table 1.3). It is common in family farms for women to manage the financial and administrative operations. Thus, even though the man is recognized as the formal head of the farm, in this way, women may also be involved in other decisions, about planting new crops or how to use agricultural resources, for example (Robbins, 2017).

Experts also note that a very critical limiting factor for rural women is not so much an issue of their personal empowerment, but they have few opportunities to obtain important information, for instance, about their rights, available services, benefits, or even about farming technologies or entrepreneurship. Rural women are cut off from information, in part due to lack of time and also the logistical difficulties, they experience in travelling to larger towns or cities. And this is isolation for them, more than their status, that prevents them from fully taking advantage of opportunities or participating in many aspects of social life.

This fact is crucial for those types of technology which classified as consumer goods, as household and small farms are the potential target audience for their further scaling.

Although they are small in scale at the level of individual households, agricultural production of the type described above is an essential activity that supports many rural families and contributes significantly to the country as a whole. In 2018, such households accounted for 43.6 percent of the total volume of agricultural production in Ukraine (also 39.5 percent and 54.2 percent of crop production and animal production, respectively) (SSSU (A), 2019).

The government has recognized the potential for such smallholder activities to be transformed into family farms, and acquiring this status would then lead to greater social protections for such farmers, and, importantly, being covered by the pension system. The 2018 changes to the Tax Code[5] (GOV UA (A) 2017.), mentioned above, seem to simplify the process by which rural residents can register as individual entrepreneurs and establish family farms, provided that they meet certain criteria (they are exclusively engaged in agricultural cultivation, members of the farm are household members, and land plots must be no less than two hectares and no more than 20 hectares) .

The States Statistics Service of Ukraine annually conducts a survey of agricultural activities among a sample of rural households. According to the most recent results, female-headed households (FHH) have smaller land plots on average than male-headed households (MHH) in rural areas, as illustrated in Figure 16. Both male and female heads of these rural households tend to be elderly, but women are older on average (average age of 62 years, compared to 57 years for men) (SSSU (A) 2018.).

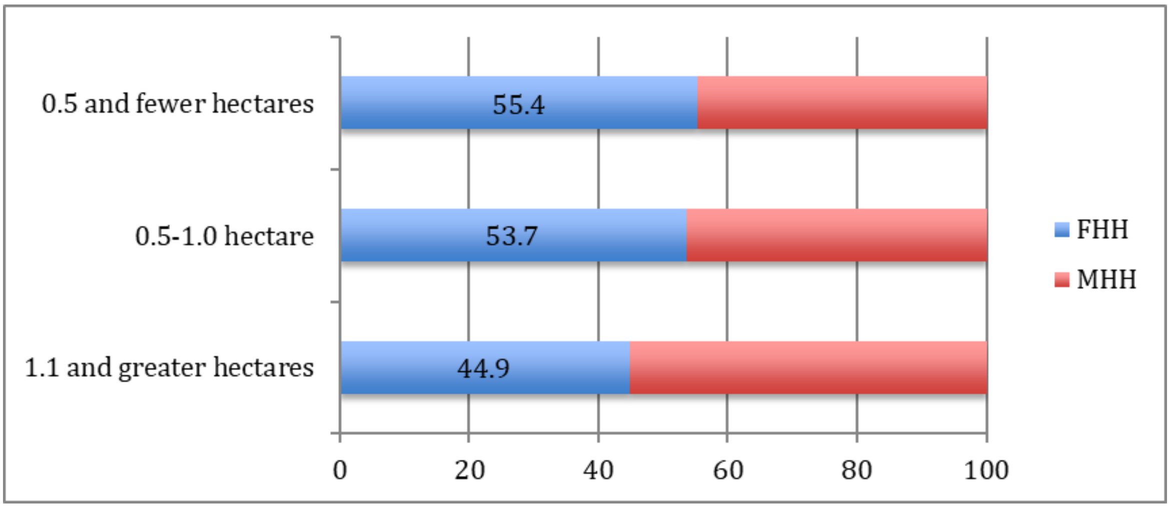

Figure 1.2. Percentage of rural households headed by women and men, by land area (2018)
Source: (SSSU (A) 2018).

Having observed differences in gender roles (e.g. women's greater responsibility for gathering food, fuel, and water), it is often the case that women have a unique understanding of what is needed to adapt to changes in the environment and can offer innovative solutions. Considering the fact that the technologies presented here were recognized as the gender-neutral, which particularly means both men and women have equal access to operate and implement them without any technical restrictions and physical limitations. Thus, to reach preliminary targets described above in this section, it is essential to effectively integrate gender opportunities in technologies transfer and take advantage of women as change agents.

[5] Amendments to the Tax Code of Ukraine and certain laws of Ukraine on the promotion of the formation and operation of family farms. https://zakon.rada.gov.ua/laws/show/2497-19.

1.2. Barrier analysis and possible enabling measures - Drip irrigation in combination with conservation agriculture practices (DICA)

1.2.1 General description of technology

Conservation agricultural (CA) practices match with three main principals[6] such as: 1) the maintenance of a permanent soil cover, 2) minimum soil disturbance (i.e. no tillage), and 3) the diversification of plant species[7] that contribute to sustainable land management. They are recognized as an effective technology for preventing soil erosion, the loss of soil productivity, saving humidity, soil thermoregulation, as well as carbon sequestration. However, in the arid land, the formation of a cover layer is a problematic and costly measure due to the lack of moisture. It can be improved by applying irrigation.

The adoption of drip irrigation in combination with conservation agricultural practices (DICA) technology addresses both mitigation and adaptation issues, as it reduces GHG emissions, while increasing crop production in the drought condition. Following the experts' recommendation, the combination of DICA is recommended for farming in land with unsatisfactory agrochemical, physical, mechanical and hydrophysical properties such as high sand content, significant content of dust and silt, soil compaction, low content of moving macronutrients and low moisture content.

Although the DICA technology requires significantly national irrigation infrastructure enhancing, particularly pump-power facilities, the technology was classified as a Capital good. Generally, it was caused by the fact that demand to be formed by the agriculture producers and forced by the market rather than the state priorities.

DICA technology is a combination of four key stages:

1. <u>Forming the crop-rotation scheme</u> is carried out in accordance with the agro-climatic features of the farm, the agrochemical soil condition and the economic feasibility of its cultivation for the farmer. Depending on soil-climatic conditions and the specialization of a farm, crop rotations vary according to composition and alternation of crops, the number of fields and their size. Crop rotations are divided into types according to the production purpose and the cultivation of certain crops, and into sorts according to the ratio of crops.

In order to increase the index of irrigated land’s use and the coefficient of growing season’s use against the background of maximal soil fertility preservation, for the extremely arid lands in Ukraine, the following intensive short-term crop rotation may be proposed:

1. Oil-seed flax
2. Post-harvest soy
3. Grain maize

<u>Oil-seed flax is</u> considered as one of the most reasonable alternatives to sunflower as the saturation of crop rotations with the latter has reached critical values in Ukraine - 15-20% (5,0-5,3 million ha).

<u>Post-harvest soy</u> - the plasticity of ultra-early varieties (75-80 days of vegetation) allows to obtain the second harvest in a season in an irrigated field.

[6] FAO UN. http://www.fao.org/resources/infographics/infographics-details/ru/c/216754/

Soy is the crop that is currently mostly dynamically developing in Ukraine. It is annually grown in all regions of Ukraine with a total area of 1.7-2.1 million ha (Demidov, 2008.). The annual gross output in recent years is equal to 4.0-4.5 million tons, determining the high 8th place of Ukraine in the world in terms of soy production (Fig. 1.3).

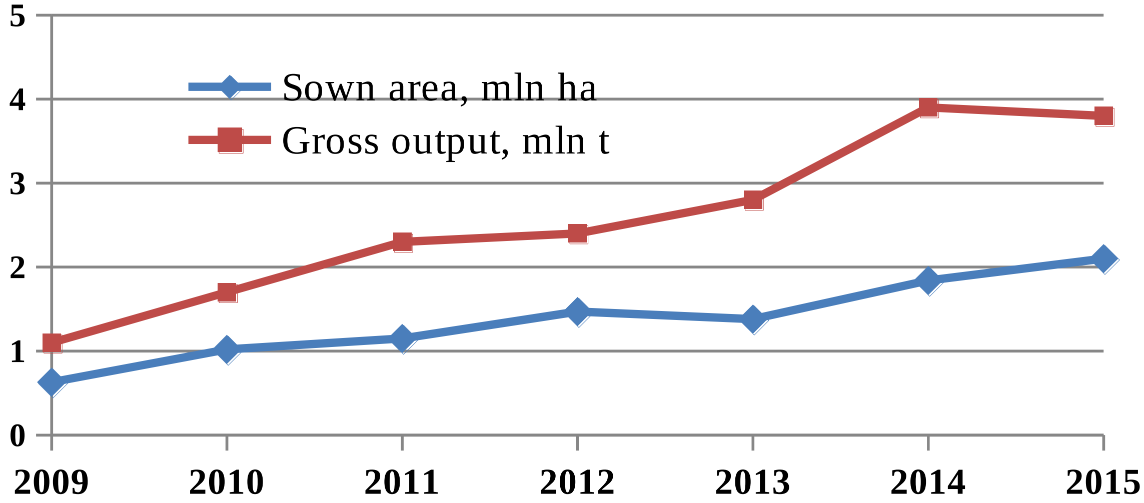

Figure 1.3. Dynamics of sown area and gross output of soy in Ukraine (2009-2015)
Source: (Shatkovski, 2014)

It should be noted that for the last few years, soy has become the fifth crop in Ukraine in terms of export (after maize, wheat, barley and rape). According to these indicators, Ukraine ranks seventh in the world.

Although the average yield of soy increased from 1.58 t/ha (2010) to 2.58 t/ha (2018), these values are lower than in highly developed agricultural countries. For example, the USA, which is the largest soy producer in the world (110 million tons in 2017/2018), the average yield of soy is **3.21-3.33 t/ha.**

Currently in the zone of the Ukrainian Steppe, there is a potential to increase the area where soy is growing. On the one hand, it is determined by crop's biological features (the optimal temperature for growth and development of soy is 28-300C), on the other hand- by the introduction of short-term irrigated crop rotations "soy - maize", "soy - barley", etc. According to the available data, about 30% of all soy plantations are located in the Steppe. About 80-85 thousand ha are irrigated. Under irrigation, the yield potential of modern soy varieties is quite significant: in 2013, the average yield of 3.44 t/ha was obtained by 87.3 thousand hectares. The best farms (State Enterprise "Kakhovske", State Enterprise "Askaniyske", Private farm «Agrotechnology», «Tavriyska perspektyva» in the Kherson region) obtained the yield of 4.2-5.1 t/ha. The **record yield values** against the background of **drip irrigation** were obtained in Private farm "Agrotechnology" on the area of 12.6 hectares and were equal to **10, 23 t**/ha (Babich, 2014).

Grain maize is a component of intensive short-term crop rotations commonly accepted in the world practice to be used after legume crops, particularly, soy.

For the last 10 years, maize in Ukraine, remarkably, "achieved a quantum leap", confidently returning the title of "Queen of Fields". In practice, this means the following: it is grown in 15-16% of all arable land in Ukraine (4.5-4.8 million hectares) and composes 25% of the export of all agricultural commodity groups. Ukraine is the second largest maize exporter (after the USA) by the volume of grain (20-26 million tons/year), the fifth largest producer (35.6 million tons/year or 3.5% of the world's total), and stands on the 12th place in terms of its consumption (10-12 million tons/year).

Sowing area and gross output of grain maize in Ukraine have increased significantly over the last 25 years (Fig. 1.4).

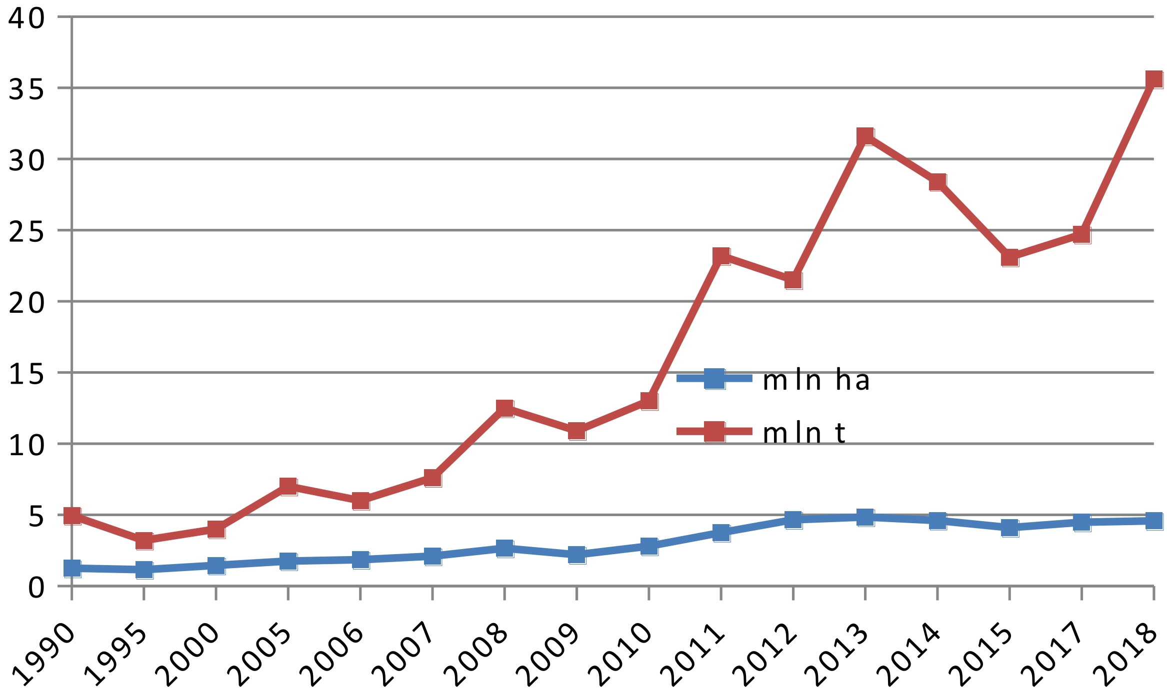

Figure 1.4. Dynamic of sown area and gross output of grain maize in Ukraine (1990-2018)
Source: developed by J. Danilenko, 2019.

However, in 2014/2015 and 2015/2016 sown areas and gross output cuts were observed (Fig. 1.2). The reason for the last (2015) decrease of grain yields, as well as it happened in 2012, was the drought in the forest-steppe and Polissya zones where the main sown areas of maize were concentrated.

The average yield of grain maize in Ukraine in recent years varies between 5.0 t/ha and 6.5 t/ha and has a trend for a growth reaching a record 7.77 t/ha in 2018. These values still remain low with comparison to average yields achieved in Spain (11.10 t/ha), the USA (10.9 t/ha), Italy (9.42 t/ha), Germany (9.66 t/ha), France (8.18 t/ha), Egypt (8.20 t/ha), and other countries.[8]

The main limiting factor of grain maize productivity in the conditions of the Steppe, the Forest-steppe, and in the recent years due to climate changes, the Polissya zone of Ukraine is in unfavorable water regime of soils that hampers the realization of agro-resource potential of these territories (Zolotov, 2010). Possible ways of obtaining high and stable maize yields in these conditions are the creation of drought-resistant, heat-resistant initial parental forms (lines) by geneticists and breeders. On their base, new hybrids of maize can be obtained along with more effective measures of varietal and zonal adaptive crop cultivation technologies and the introduction of soil cultivation technologies aimed at the maximal maintenance of soil moisture and improvement of soil fertility - no-till, mini-till, strip-till, mulching, snow retardation, etc. According to the practice and scientific studies, in these conditions, the most effective is a combination of the aforementioned soil cultivation technologies and irrigation reclamation. The most effective growth of yield results from the optimization of water and nutrient regimes and

[8] Maize production worldwide (in Ukrainian) https://www.yara.ua/crop-nutrition/maize/key-facts/world-production/

ranges from 110 to 380% comparing with the conditions without irrigation (Shatkovsky, 2010).

2. The installation of subsurface drip irrigation combined with efficient water usage regimes. The implementation of this technology requires the preliminary preparation and the approval of project documentation for the irrigation system and is subject to regulation in accordance with the Law on Environmental Impact Assessment No. 29 dated 18.12.2019. The undersurface drip irrigation system in the combination with CA was selected for application. The detail description for the Cost of construction under drip irrigation system was provided in Annex IV A, Figure IV A -01.

This irrigation methods have a number of environmental, design and engineering requirements that provide the highest level of safety in terms of their impact on soil and the environment:

Drip irrigation systems (DIS):

- The use of synchronous systems designed for water supply according to average water consumption of crops in daily cycle;
- The use of irrigation pipelines (IP) with the wall thickness of more than 0.4 mm. This value has been proven to ensure a long operation period;
- the use of pressure compensating emitters which ensures the most uniform irrigation along the length of IP;
  In addition, the systems of subsurface drip irrigation (with the placement of IP at the depth of 20-40 cm) are now, potentially, more efficient due to:
- irrigation water saving (minimization of physical evaporation from soil surface) - from 10 to 25%;
- a significant reduction in pesticide load - the number of chemical treatments of crops (plantings) is reduced by 2 times due to decrease in the weed infestation of crops (weed seeds resides in the upper layers of soil that are not watered) and decrease in the illness frequency of plants from 5 to 20%. The latter is due to the decrease of air humidity that diminishes the appearance of plant diseases caused by phytopathogenic fungi;
- the saving of resources and labor for the installation and the dismantlement of irrigation pipelines;
- the saving of resources and labor for the service operations of irrigation systems;
- 100% technological effectiveness (the ability to freely carry out agrotechnological operations: spraying, inter-row cultivation, hilling, harrowing, fertilization, etc.);
- The impossibility of irrigation pipelines' damages caused by mechanisms, workers, birds, etc.;
- possibility to choose maximally technological schemes for sowing (planting) of vegetables and other tilled field crops.

Operative irrigation management and rated water use are another important components of irrigation system. The majority of modern methods for determination of soil moisture belongs to the group of indirect methods, the subgroup named "point measurements by installation of sensors at representative points" and are based on the determination of parameters that are in close correlation with soil moisture: the capillary potential of soil moisture, dielectric conductivity, the intensity of the polarization of electrodes have been introduced into soil, etc. Such technical devices as Diniver-2000 and EnviroSCAN (Australia), SM200-UM-1.1 (Great Britain), CropSense (USA), Sentek (Australia), Watermark (USA), IRROMETER (USA), multisensory probe AquaSpy CTG-02 (USA), etc. are among the most famous devices in the recent past and today.

3. The application of the no-till or mini-till practices for soil processing. The technological basis for transition to conservation agriculture (No-till) is the availability of hard component: seeding equipment for direct seeding technology with the appropriate predetermined design of the sowing coulter.

For that type of soil which has unsatisfactory properties - low content of humus and high bulk density, after the first cycle of crop rotation, it is recommended to sow cover and green manure crops.

For soil loosening, we recommend sowing such cover crops as radish, mustard, garden radish, and turnips. The root system of these crops penetrates through the dense layers of soil, naturally destroying the plow sole. The action of a sturdy root system of these crops on the land is typically called the use of a "biological plow." The best seeding period is the 4-5 leaf phases of maize development. Thus, at the time of maize harvest (from the end of August to the beginning of September), cover or green manure crops will be well-developed and will almost completely cover the soil. Watering the covering crops occur along with the watering of the main crop. It helps to increase water and energy usage efficiency.

The function of green manure crops is the accumulation of organic matter. For this purpose, a mixture of cereal crops that have a high ratio of carbon to nitrogen content is best suited. Moreover, the recommended list of crops includes oats, barley, triticale, rye, millet, sorghum, and wheat.

In addition to the two above-described functions, cover and green manure crops perform such other essential functions in the soil-protecting no-till system as: accumulation of plant residues; - the accumulation of available nitrogen in the soil; the promotion of the "transition" of nutrients (phosphorus, potassium) from inaccessible forms to the forms easily accessible to plants; the reduction of weed infestation; resettlement of mycorrhiza.

Thus, crop rotations that include the cover and green manure crops improve the physical, mechanical, water-physical properties of soil provide a balance of nutrients and help to reduce the problems caused by weed infestation of fields.

4. Enhanced application for integrated pest management principles.

Even general estimation of crop production economy efficiency demonstrates the significant advantages of DICA application for soybean and grain maize production in comparison with conventional agriculture.

Table 1.4. Crop production economy efficiency: DICA vs Conventional Agriculture

Items	**Conservation Agriculture**		**Conventional Agriculture**	
	Soybean	**Grain Maize**	**Soybean**	**Grain Maize**
Project documentation, $	N/A. Cost per hectare depends on the size of the plots. Tentatively, the minimal cost is about $ 5000 per project.			
Subsurface drip irrigation system construction[9], $ per ha	1 596	1 596		
Seeders and the other types of machinery	N/A. Cost per hectare depends on the type of machinery and size of the plots.			
Maintain cost, $ per ha	from 400	from 400	from 420	from 420

[9] The detailed local cost estimation for drip irrigation system construction is in the in Annex III A, Figure III A -01

Yield, t per ha	10	7 -9	4 -5	5 -6
Market price, 2019, $ per tone	370	170	370	170

Moreover, the application of the DICA technology has a set of additional benefits in comparison with other crop cultivation technologies:

- Stable and predictable production under the droughts and water sacristy;
- The increased efficiency of waters usage (reduced evaporation losses from the soil surface) from 10 to 25%;
- The significant reduction of pesticide load – the number of chemical treatments of crops is reduced to 2 times due to the reduction of weed infestation of crops (weed seeds are in the top layers of soil that are not moistened);
- The reduction of plant diseases from 5 to 20%;
- The saving of resources and labor costs for operating the irrigation system;
- maintaining 100% operational adaptability (possibility to freely carry out agrotechnological operations such as spraying, inter-row cultivation, hilling, harrowing, plant nutrition, etc.);
- the exclusion of damage to the irrigation pipes by mechanisms, workers, birds, etc.;
- the possibility of choosing the most technological and economically feasible planting system of vegetable and other row crops;
- increasing labor productivity by 3-5 times;
- the reduction of labor costs by 1.6 times, purchase of equipment – by 1.5 times, fuel - by 2.2 times. Considering the costs of water, fertilizers, lime, herbicides and insecticides, and labor, the estimated savings of operational cost will be around 16%;
- increasing the likelihood of maintaining the base yield in dramatic climatic conditions;
- the optimization of water balance and water quality in the region;
- significant increase in soil organic matter content and humus due to the use of crop residue cover as organic fertilizer;
- the improvement of the soil condition, soil protection from erosion, deflation and anthropogenic compaction;
- improving the agrochemical soil condition with sufficient moisture, increasing the utilization coefficient of plant nutrients and mineral fertilizers, especially phosphorus (especially at moderate application doses) due to the localization of fertilizers and the root system and the most biologically active surface layer;
- leveling the field surface whereby improving working conditions of machine operators, the operation of technical means and reducing vibration loads on the human body and metal.

The principles of operational irrigation management lay on the grounds of the technology application. DICA is based on the implementation of optimal ecologically safe irrigation regimes and ecologically safe irrigation norms, which is used to eliminate the cost of irrigation water for infiltration and, accordingly, minimizes the risk of flooding.

The irrigation intensity is determined by the conditions of plant's germination and vegetation, taking into account the condition of the plants, the moisture's content in the root layer of soil, changing weather patterns, etc.

Currently, the market capacity defines with the medium and large-scale farms (from 100 hectares in processing), nearly 4,200 farms. Numbers mentioned above are based on the existing interest to the CA among farmers in Ukraine. Thus, the No-till and its variants (mini-till, strip-till) are quite successfully applied in many agricultural enterprises with various forms of ownership and areas of land to used that are located in different climatic regions of Ukraine ("Agro-Soyuz", Dnipropetrovsk oblast; "Agro-Myr", Kirovograd oblast; "Pischanka", Kharkiv oblast; farm enterprise "Beskydy", Rivne oblast, etc.). According to approximate estimates, about 600,000 hectares of land are cultivated by using conservation agriculture technologies. However, a number of farmers refuse to use the technology because of the impossibility of achieving the maximum yield efficiency in the short term by applying no-till, especially on high-yield lands. That is why, the application of this technology is recommended on low-productive soils since, in combination with the use of irrigation, this technology allows to maximize the efficiency of agricultural production (example of LLC Zorya-Yug, Mykolaiv).

CA farming in Ukraine continues to shape, even in the absence of targeted support from government agencies and generally scientifically weak base of support for the new farming system. At the same time, the leading networks and elements of irrigation systems, such as reservoirs, canals, and pumping stations were built, taking into account the prospect of irrigating the area of 4.25 million hectares. Therefore, the combination of conservation agriculture with drip irrigation has the potential for expansion in spite of the its cost.

The following limitations for the technology application can be defined:

1. The shortage of adequate quality water resources for drip irrigation.
2. DICA is not recommended to apply on well-moistened or slightly drained lands.
3. Competition with biofuel production. Remaining the crop residues on the field is the critical principle of CA, which makes it impossible to use as raw materials for bioenergy purposes
5. Usually, the DICA is incompatible with organic farming.
6. The high chance of reducing the seed germination due to the saturation of the sowing layer with crop residues that requires an increase in seeding rates by 15-25%.
7. The costs of weed control increase by 15-100% with comparison to conventional cultivation, depending on crop and crop rotation type.
8. Intensive weed control increases the risk of emergence of herbicide-resistant weed populations.
9. There is a risk of salinization or acidification of the soil due to the wrong irrigation regime.

1.2.2 The identification of barriers for technology

The identification of barriers and opportunities to overcome them were conducted in the framework of the Second Edition of Guidebook on Overcoming Barriers to the Transfer and Diffusion of Climate Technologies developed by (UNEP DTU, 2015).

As the first step, the long list of barriers for each of the technology was produced on the basis of both reviewing the relevant literature from various sources, including open internet sources, as well as discussing and interviewing specialists with significant expertise in the area. At the same time, the work was conducted within each sectoral working group (WG) formed of project experts on the CC adaptation of agriculture, deputies of relevant institutions and agencies (Annex V).

The preliminary lists of barriers were shared among the members of sectoral FGs for further discussion. The dates of the consultation were appointed for each working group. Stakeholder's consultation was conducted through organized workshops and extended on-line: Working Group DICA technology workshop (23rd December, 2019, Kherson, Mykolaiv); Working Group Agroforestry technology workshop (December 09, 2019, Kyiv-Kharkyv), Annex V.

In this regard, to define weight and barriers significant to screen them, the set of criteria was proposed. Each barrier was to estimate with its relevance to:

- The availability of relevant state support (direct and indirect subsidies, fiscal relief, favorable investment conditions, strategical programs of development so on);
- conducive legislation on the national level (national laws);
- the precise legislative mechanism on the local level (executive-legislative mechanisms);
- human operational capacity (suitably qualified workforce available education programs and training, etc);
- infrastructure capacity;
- the availability of technology;
- competitive advantage;
- the level of dependence from the direct government management/solution (UNEP DTU, 2015)

Further, barriers were categorized following the guidance of the above-mentioned Guidebook (UNEP DTU, 2015), including the categories of barriers, such as killer (non-starter), crucial, important, less important, insignificant (easy starter).

Besides, potentially strong measures were estimated and proposed towards technology transfer and dissemination.

A number of barriers to the further development of Drip irrigation in the combination with conservation agriculture practices have been preliminary listed in the random order on the basis of the literature review, open internet resources and interviewing of the relevant representatives of the academy, government, public, and business:

1. the absence of an effective agricultural land market
2. Lack of state financial supporting mechanism for the implementation of technology
3. Uncertain future in terms of national currency instability, political instability, lack of supportive mechanism
4. Long-term pay-off period
5. Relatively high investment cost
6. Poor conditions of irrigation infrastructure
7. Low level of awareness
8. Low priority of CC adaptation measures
9. Lack of relevant study programs on the field of agronomy, integrated natural resource management as well as the on-line courses for the farmers and/or extension services.
10. Inefficient Extension services
11. Insufficient skilled manpower
12. Insufficient knowledge
13. Lack of systematic research particularly: modeling of impact from the conservation agriculture application on the water usage regimes by crops, regions, soil types and etc.
14. Absence of relevant data and information
15. Availability of machinery and necessary equipment
16. Cost of implementation and maintenance
17. Depletion of water resource
18. Migration of the rural population
19. The demographical situation on the rural areas

20. Low interest to conservation agriculture practices from government and academic side
21. Conflict of interest between conservation agriculture from one side as well as bioenergy technologies and conventional agriculture technologies as incumbent technologies.
22. Increasing the pesticide loads as a result of CA implementation

Further, during the discussion under the workshop in Kherson, 23rd December, 2019, barriers from the long list were screened according to their significance. As a result, shortlist of the crucial barriers for the technology transfer and diffusion was produced (Table 1.5.) and barriers categorized according categories. Barriers were recognized as non-essential were discarded and ignored subsequently.

Table 1.5. Short list of the Barriers Screening for DICA technology

#	Barrier	Barrier category	Influence quantity
1	The absence of an effective agricultural land market	Legal and regulatory	CRUCIAL
2	Poor conditions of irrigation infrastructure	Economic and financial	CRUCIAL
3	Insufficient skilled manpower	Institutional and organizational capacity	CRUCIAL
4	Low level of awareness	Information and awareness	IMPORTANT
5	Lack of state financial supporting mechanisms	Legal and regulatory	IMPORTANT
6	Relatively high investment cost	Economic and financial	IMPORTANT
7	Long-term pay-off period	Economic and financial	IMPORTANT
8	Insufficient knowledge	Information and awareness	LOW IMPORTANT
9	The low priority of CC adaptation measures	Legal and regulatory[10]	LOW IMPORTANT
10	Inefficient Extension Services	Institutional and organizational capacity	LOW IMPORTANT
11	The absence of relevant data and information	Information and awareness	LOW IMPORTANT
12	Lack of systematical research	Network	EASY STARTER
13	Lack of communication	Network	EASY STARTER
14	Lack of relevant study programs	Human skills	EASY STARTER

Then barriers were decomposed, and the simplified problem tree was developed (Figure 2.2.).

[10] This barrier could be institutional as well and, typically, this is one of the major barriers why adaptation measures are not implemented, as they are not prioritized on government agenda. Despite it, Ukraine does not have the climate change adaptation policy on agriculture, the DICA technology is developing and getting more popular. That is the reason, the barrier was classified with a low important impact.

1.2.2.1 Economic and financial barriers

Relatively high investment cost. The DICE is a comprehensive practice combining the two technologies; surface drip irrigation and conservation agriculture. In this regard, the DICA's economic and financial barriers are the complex of barriers of each technology plus the general irrigation infrastructure barriers.

The relatively high investment cost is the barrier for farmers and agriculture producers due to the high capital cost of technology (described below) as well as the high domestic refinancing rate 13,8 and the average loan rate - 16,5% (February 2020).

The acquisition of a subsurface irrigation system and the costs of its installation vary according to the country of manufacturing output and specifications (the price ranging between $1,800-$18,000 per hectare). The cost of the irrigation system depends largely on the availability of its own water source and the requirement for drill additional irrigation well. When drilling is required, design project's documents, permits and environmental impact's assessment are required, which increase the implementation costs of technology.
Nonetheless, the proposed approach of irrigation significantly increases crop's yield, reduces water costs, and may cover the additional expenses for its installation for two seasons. Additionally, farmers may obtain compensation buying the nationally produced irrigation equipment up to 50% from its price (GOV UA (B).

The implementation of the CA approaches is the main challenge for farmers, as there is a high chance that switching to the CA would cause decrease in yield in the first two-three years of implementation. Besides, the purchase cost of the machinery complex for sowing can range between $7,000-$40,000 per hectare and depends on the country of manufacturing. Operating expenses include the acquisition of seeds, fuel, lubricants, water, plant protection agents, labour, equipment rental etc. The average level of operating expenses can vary from 00 to 700 US dollars per hectare, depending on the field's conditions. Thus, all these reasons could increase the pay-off period which experts recognize as an *important barrier* for the further technology deployment.

Poor conditions of irrigation infrastructure. Following the Strategy of irrigation and drainage in Ukraine by 2030, only 10 percent of the total irrigation infrastructure capacity is used. Another part requires to be renovated and reconstructed. However, restoring the performance of damaged parts of the irrigation infrastructure will require considerable investment and developing the relevant equipment. Tentatively, about $ 3 US billion should be invested in irrigation infrastructure to expand its irrigation capacity up to 1,180,000 hectares.

1.2.2.2 Non financial barriers

The following set of the non-financial barriers were identified and screened:

The absence of an effective agricultural land market. In 1991, 6.9 million villagers (about 16% of the total population) received 27 million hectares of agricultural land (about 45% of the country's total) into private ownership by splitting up the land banks of former collective farms. At the same time, 28.8 million hectares (47.8% of the total) remain state-owned or communal-owned (of which about 10.5 million hectares is agricultural land). Due to the moratorium to buy or sell agricultural land, typically, the private agricultural land is only for rent.

Currently, about 4.7 million private owners (70% of the total) lease their land to agricultural producers. The total capacity of the official rental market is about 17 million hectares. However, the lease market of official agricultural land is suffering from the limitation of the lease term.

The shortest official lease term of the agreement is for seven years. As a result, the lease agreement with the term shorter than seven years is unofficial and created the gray market.

These problems lead to inefficiencies in the agricultural sector: the limitation of access to finance, since land cannot be used as collateral; reduced incentives for investment and sustainable land use; reduced rental and tax revenue and asset value for landowners. Besides, non-transparent use of public land, and numerous conflicts of interest in the management of community land, lead to corruption, loss of budget revenues, inefficient and unstable land's usage.

Insufficient skilled manpower one of the most complicated barriers to overcome, which is highly time-consuming. This barrier was caused by the set of reasons, such as the low conditions of life and the wage disparities in rural areas, the high level of working migration, absence of the relevant education programs on CA and irrigation, the insufficient interest of young people to work in the agriculture sector and other. The agricultural sector is quickly developed with new technologies. The production is being automated, which generates the demand for specialists who will be able to work in modern farms equipped with the robotic machinery. Moreover, experts noted that it is a problem for employers and job seekers to find each other.

Low level of awareness. At the national level, there is no particular organization, authority, or permanent project providing the data, information analysis, and modeling the climate changes and their influence on the agricultural production. Hydro Meto Centr is only organization, which supplies the climate relative data to farmers, government and non-governmental organization. However, the technical capacity of the Ukrainian Hydro Meteo Center is insufficient to satisfy the current requirements of agricultural producers, due to low quality, low level of resilience and relevancy. The observation system, approach to data collection both technical and methodological requires modernization.

Lack of state financial supporting mechanisms. Considering the government's position, the state's financial support for the agricultural sector might be directed towards increasing the production, creation of employment and strengthening the exporting capacity of agricultural and food products. The payment/subsidies for ecology or ecosystem services or support for climate change adaptation is not foreseen.

Insufficient knowledge. To implement and operate the DIVA, the highly qualified staff is required. People with knowledge of the operation the drip irrigation regimes as well as agronomists skilled in the CA and processing with no-till sowing machinery are limited. Currently, there is no educational program in agronomy at school or specific professional education /vocational education. Moreover, only two Universities among the 36 have courses on irrigation and land reclamation. This creates total lack of specialists with relevant knowledge to implement this kind of technology. However, experts agree that it is possible to develop and improve the education process with courses and study practices in one year. Actually, academy and farmers have enough technical, practical, and human capacity to solve these problems

The low priority of CC adaptation measures. The low interest of the relevant top-government to CC adaptation in agriculture may be observed. On the governmental level, the situation in agriculture seems to be stable, crop production has been growing for the recent decade and producers are neither complaining, nor they ask for policy support. Despite it, farmers are facing significant consequences of climate change, the broken communication with government creates the situation, when the agricultural policy in terms of CC mainly directs to the mitigation. This barrier could be institutional as well and, typically, this is one of the major barriers why adaptation measures are not implemented, as they are not prioritized on government's agenda. Despite it, Ukraine does not have the climate change adaptation policy on agriculture, the DICA technology is developing and getting more popular. That is the reason, why the barrier was classified with a low important impact.

Inefficient Extension Services. The extension services in Ukraine has enough strong regulatory base for development on the national level. The section 404 of the Association Agreement between Ukraine and the EU provides that cooperation between the two Parties in the field of agriculture and rural development. Cooperation shall cover, in particular, the knowledge and technology transfer to agricultural producers through the extension services. Conditions for the provision of socially directed extension services are defined in Order (GOV UA, 2007). However, in practice, extension services are not popular on the local level. Despite the state support of the extension services, farmers are developing professional networking which they are more preferable and trustful.

The absence of relevant data and information. Carrying out the TNA project, the practical examples of the DICA technology implementation was identified in Ukraine. Moreover, the two research institutes (Water problem and reclamation (Kyiv) and Irrigated Agriculture (Kherson)) are conducting the research projects on the CA and irrigation in the southern regions of Ukraine. At the same time, a lot of data were collected in the process of the implementation of GEF FAO project[11]. However, the data was not gathered and collected in one place. There are not systematical official information and data about the CA in Ukraine, the assessment of losses in the result of the changing of the temperature and water regime so on. Available data split up among the different holders, such as research institutes and other state organizations, farmers, laboratories. Thus, data is not homogeneous, relevant, and collected in one place.

The three barriers such as (i) Lack of systematic research, (ii) Lack of communication and (iii) Lack of relevant study programs were classified as easy starter barriers due to the possibility of being overcome in the short-term.

The compromised food security, unsustainable land management and vulnerable livelihood are the key factors, but not the fully listed backwashes of the braking in the DICA technology development.

The problem tree on the DICA technology is presented in Annex I A, Figure IA-04.

1.2.3. Identified measures

The enabling measures were identified in the process of consultations with experts following the next input parameters:

- Realistic measures should be politically, mentally, culturally, and technologically relevant and easily integrated into the current living conditions in the country.
- At least the initial level of the legislative framework and institutional capacity have been already created for the implementation and conduction of the suggested measures.
- Time frame. The measures can be implemented in short-term prospects.

1.2.3.1 Economic and financial measures

Despite the considerable requirement for funds, the renewal of irrigation system is attractive in terms of increasing the general economic potential of the region, including agriculture. Thus, experts did not recognize the high cost of investment in developing the irrigation which farmers

[11] Integrated Natural Resources Management in Degraded Landscapes in the Forest-Steppe and Steppe Zones of Ukraine https://www.thegef.org/project/integrated-natural-resources-management-degraded-landscapes-forest-steppe-and-steppe-zones

using currently and technology as a crucial barrier due to the investment attractiveness of the sector and existent government support (covering 50% of price) to the industry.

The support for developing the infrastructure of irrigation and water reclamation is included as a part of the country program's framework for the World Bank and EBRR.

Currently, conducting the reform of decentralization provides more freedom to form and operate budget resources at the local level. Thus, united village councils would be able to seek money for the irrigation infrastructure developing under the local budget.

More detail of the economic and financial measures described in the Table 1.6.

Table 1.6. Economic and financial enabling measures for DICA technology

#	Barrier	Enabling Measures
1	Poor conditions of irrigation infrastructure	1. Financial support from the international donor organizations such as the World Bank and EBRR. The amount of the financial support is $ 200 mill doll USA. The support aims at enhancing the competitiveness of agriculture, diversifying, and developing it by improving the effectiveness and targeting of agriculture support policies, improving transparency and efficiency of agricultural land usage. 2. Increasing budget for the improvement of irrigation infrastructure under the National Dnieper Basin Environmental and Drinking Water Quality Program (DBE&DWQ). 3. Forming revolving funds for the facilitation of irrigation infrastructure at the level of united village communities. Corresponding to the reform of the decentralization, the local level with own budget is represented by the united village counsels (OTG). 4. Developing the mechanisms of legal regulation mechanisms to transfer the ownership rights on the objects of the irrigation infrastructure to long-term free use for water users' organizations
2	Relatively high investment cost	1. Increasing capacity of the Partial Agricultural Credit Guarantee Fund to decrease the loan ratio 2. The extension of the state program for partly compensation of purchase expenses on agricultural types of machinery and equipment by the irrigation equipment
3	Long-term pay-off period	1. The optimization of the production cycle 2. Cross-subsidization and production diversification 3. Argo insurance

1.2.3.2 Non financial measures

Enabling measures which can be developed under existing national environment presented in the Table 1.7.

Table 1.7. Non-financial Enabling Measures for DICA technology

#	Barrier	Enabling Measures
1	The absence of an effective agricultural land market	i. The abolition of the moratorium on land's sale is scheduled for October 2020. Draft Law on Amendments to Certain Legislative Acts of Ukraine on the Circulation of Agricultural Land is in the process of voting. The land market might be open, if the majority would support the draft law;[12] ii. The clear and transparent mechanism for land market liberalization developed and incorporated into the law;
2	Insufficient skilled manpower	1. Facilitating the professional network among farmers and promoting the successful examples of technology implementation; 2. Moving towards decreasing the wage's disparity; 3. Developing the relevant courses of in-service education for farmers with further dissemination through the NGO or professional networks; 4. Launching the summer schools on natural resources management and agriculture at the school level in the regions.
3	Low level of awareness	1. Adopting the Strategy on mitigation and adaptation to climate change (agriculture component included); 2. The incorporation of the climate change indicators into the official statistical and reporting system for enterprises; 3. Developing and integrating the issues related to climate change into the scope of extension services; 4. Developing short animated videos and spreading through social networks.
4	Lack of state financial supporting mechanisms	1. The optimization of the approach to the redistributing the budget money such as the "ecological" funds; 2. Developing the mechanism to attract the international "climate" or "green" payments under the CA development.
5	Insufficient knowledge	1. The development and popularization of the educational web-channel for technology promotion; 2. The extension of the master program in agronomy with the proposed technology and developing on-line course available for all relevant Universities and Institutes; 3. Involving farmers and leading experts as lecturers; 4. Strong cooperation between farmers and academy by using the acting innovative farming and the best practices as a study objects; 5. Creating the open base of the best practices and success stories.
6	Low priority of CC adaptation measures	1. The acceptance of the draft of Strategy for Climate Change's mitigation and adaptation strategy of agriculture;

[12] Draft Law on Amendments to Certain Legislative Acts of Ukraine on the Circulation of Agricultural Lands https://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=67059

		2.	Conducting a study of a quantitative assessment of climate change risks by sub-sector and regions on agriculture;
		3.	The economic assessment of the climate change's impacts on soils, water reservoirs and biodiversity, improving the productivity of land and water resources.
7	Inefficient Extension Services	1.	The creation of the guideline for the technology implementation by oblast following the climate conditions and technological capacity;
		2.	The creation of the common database of the available machinery and equipment and technologies to satisfy a variety of demands;
		3.	Conducting the relevant pieces of training for advisers.
8	Absence of relevant data and information	1.	Developing the national environment monitoring system on the basis of the official data;
		2.	Developing the platform for crowd science to collect data about rapid temperature fluctuation, diseases, plants, weed spreading and etc;
		3.	Reconciliation national and international data standards (such as soil classifications, the analysis of water quality and so on).

The main possible result from the measures developing were analyzed and presented in Figure 1.5.

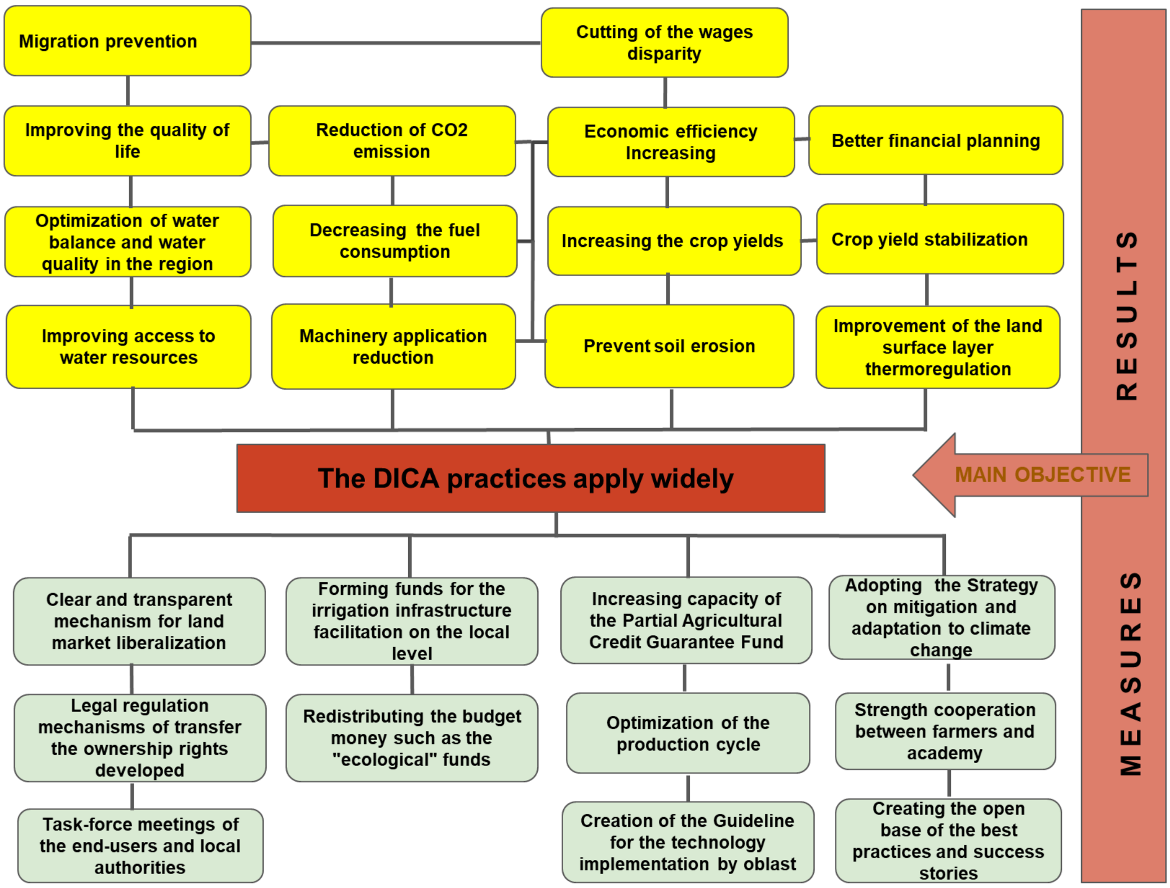

Figure 1.5. Simplified Objective Tree: Drip irrigation in the combination with conservation agriculture technology.

1.3. Barrier analysis and possible enabling measures - Agroforestry practices (shelterbelt reconstruction)

1.3.1 General description of technology

Designing forest shelterbelts, particularly the introduction of agroforestry practices play extremely an important role in the integrated system for the measures of land use contributing to agricultural productivity by adapting to climate change. Shelterbelts allow to carry out effective agricultural activities since protecting crops from damaging winds, improving the microclimate of fields, preserving water-saving, regulating spring and stormwater runoff, reducing soil erosion, etc. In the TNA classification, the agroforestry practice should be recognized as a public goods.

Principles of shelterbelt establishment (FAO (A), 2019.):

1. Shelterbelts in Ukraine should be established in all natural and climatic zones based on the agro-climate zoning.
2. The composition and position of tree and shrub species determine the resilience and long life of the shelterbelts as well as their protective value.
3. The species selection should be performed in baseline with the climate-smart forestry recommendations (FAO (B),2019).
4. The supportive species should be selected from shade-tolerant species, capable of growing in the second layer of the stand and not competing with main *spp* for light, water and minerals.
5. Shrubs perform the soil protective role in the stand; they contribute to snow accumulation.
6. Depending on the purpose and growing site’s conditions, shelterbelts can be established as pure (composed of one tree species) or mixed (having two or more tree species in its composition) ones
7. Open-air blowing shelterbelts can be established by using the main species alone.
8. When selecting a range of tree and shrub species for the shelterbelt, biological characteristics of the species should be considered and their interaction as well as natural and climatic conditions and land reclamation tasks.
9. Shelterbelts should be planted by using seedlings, saplings, rooted cuttings or by sowing seeds of not less than 2nd quality class (local collection from the best tree stands or collected in other areas provided by silvicultural zoning).
10. Planting and sowing should be made in parallel rows with the following spacing between the two rows:
    - in the Forest-Steppe zone (TNA A, 2019.) on all types of soils and northern part of the Steppe zone on typical and ordinary chernozems (black soil) – 2.5–3 m;
    - on the southern chernozems (black soil0 – 3 m,
    - on dark chestnut and chestnut soils – 3–4 m;
    - on sands of all zones – up to 3 m.
11. The size of the edges on each side of the shelterbelts is assumed to be equal to half the width of the inter-row spacing.
12. In Forest-Steppe and Steppe, soil cultivation should be aimed at maximizing the accumulation and conservation of soil moisture. It should be made in a certain system, taking into account the soil and climatic conditions, and the state of the site allocated for planting (Table 2.4.).

Minimum forest cover required for field protection varies widely and depends on the agroclimatic zone and soil type, for the soil of the clayey and loamy forest-steppe zone, it is 2.5%, and for the sandy soils of the steppe - 9.8.

Key stages of technology implementation:

- the inventory of existing shelterbelts;
- geodesic works and including shelterbelts data in StateGeoCadastre (where required);
- soil quality analysis;
- designing planting project;
- shelterbelt establishment;
- shelterbelt maintenance.

Table 1.8. Soil cultivation system in shelterbelts

Soil types	Actions	Note
Typical black soil, dark grey and grey forest soils	Stubble plowing simultaneously or subsequently to harvesting crops, primary plowing 27–30 cm, spring harrowing before planting or sowing	The area not overgrown with weeds
	Stubble plowing, spring harrowing and spring-and-summer cultivation of fallow land, autumn no mouldboard loosening, spring harrowing before planting (sowing)	The area overgrown with rhizomatous and root-sucker weeds
Ordinary black soil	Stubble plowing 27–30 cm with the deepening of plowing layer up to 35–40 cm, spring harrowing and spring-and-summer cultivation of fallow land, autumn mouldboard loosening, spring harrowing before planting (sowing)	
Southern black soil and shallow ordinary black soil in the east	Primary plowing is deep breaking to 40–50 cm and the rest is according to the cultivating system for ordinary chernozems	Autumn planting is allowed at wet soil
Dark chestnut soil	Primary plowing is deep breaking to 60 cm followed by a fallow period	
Chestnut-alkali soil complex	Primary plowing is deep breaking to 60 cm followed by a fallow period	When a layer of soil with readily-soluble salts is turned to the surface, two-year fallow period is needed
Sandy soils of Steppe and Forest-Steppe	No deep mouldboard loosening to 60–70 cm in strips 0.9–1 m in width; uncultivated strips with natural vegetation should be left between cultivated strips for anti-erosion purpose. The uncultivated strips should be gradually narrowed when caring for pine plantings	The main preparation of soil should be carried out in the autumn at spring planting of shelterbelts; at the autumn planting, it should be a year before
Deep black soil -like sandy loam soils	Primary plowing is the same as for the types of soils common in this zone (deep and ordinary chernozems)	

Relevant equipment and materials: maps and satellite images, drones (as possible), equipment for deep plowing and planting seedlings (own or rented), planting material and appropriate plant-protecting agents, etc. All equipments are not unique and generally available in the Ukrainian market. Plant *spp* are selected in accordance with the agroclimatic conditions and expected result, e.g. design shelterbelt with tree species that can be used for energy purposes, fruit, nut or berry plants can improve the economic feasibility of shelterbelt.

Following the main findings of the survey, conducted by FAO under the implementation GEF project (FAO GEF, 2019), two-thirds of the communities surveyed (including 86% of the communities from risk farming zone) believe that there is a need of restoration for the protective shelterbelt. As for the construction of new land underneath shelterbelt, only 10% answered positively (Figure 1.6.).

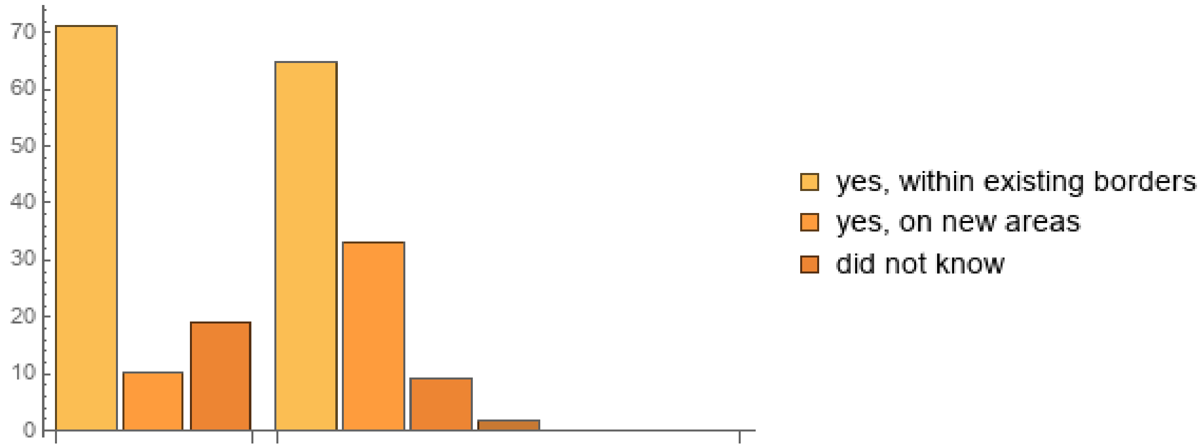

Figure 1.6. Respondents' answers to the question “Do you consider it necessary to install new or renewed existing forest protection strips in the territory of your territorial community?

Source: (FAO GEF, 2019)

Technological potential - there is a satisfactory provision of necessary equipment by international and national manufacturer. However, there is a shortage of quality planting material.

The implementation of this technology requires to carry out the survey of land boundary in accordance with the Land Code of Ukraine (dated 25.10.2001) and the development of appropriate project technical documents for the establishment and/or reconstruction of shelterbelts with subsequent registration. In addition, agrochemical soil analysis will be required in accordance with DSTU (National Standard of Ukraine). There is no government support program.

According to Law № 2498-VIII dated from 10.07.2018, shelterbelts are assigned to agricultural land and their transfer to the use of Amalgamated Village Communities is regulated. AVC can create public utility companies and fix in shelterbelts for sustained use.

Growing a variety of crops in close proximity to each other can create significant benefits to producers, such as the improved crop production and microclimate benefits and help them to manage risk.

Alley cropping is defined as the planting of rows of trees and/or shrubs to create alleys within which agricultural or horticultural crops are produced (Figure 1.7.). Trees may include valuable hardwood veneer or lumber species; fruit, nut or other specialty crop trees/shrubs; or desirable softwood species for wood fiber production.

Some producers plan alley cropping systems to provide additional functions that support and enhance other aspects of their operation. For example, a livestock producer might grow crops that supply fodder, bedding, or mast crops for their livestock. Some producers may be interested in how alley cropping can support soil health. Other producers may want to produce biomass for on-farm use. Organic producers may choose tree species that fix nitrogen.

The versatile nature of this practice allows a producer to react to markets, labor limitations and changing goals.

Forest Farming – grows and protects high-value specialty crops under the forest canopy, which is adjusted to the correct shade level and the preference of crops. This is done by thinning an existing forest to leave the best canopy trees for the continued timber production while creating ideal growing conditions for the understory crop. Non-timber forest products grown using forest farming methods don't just provide an additional source of income – they also help conserve habitat for wildlife.

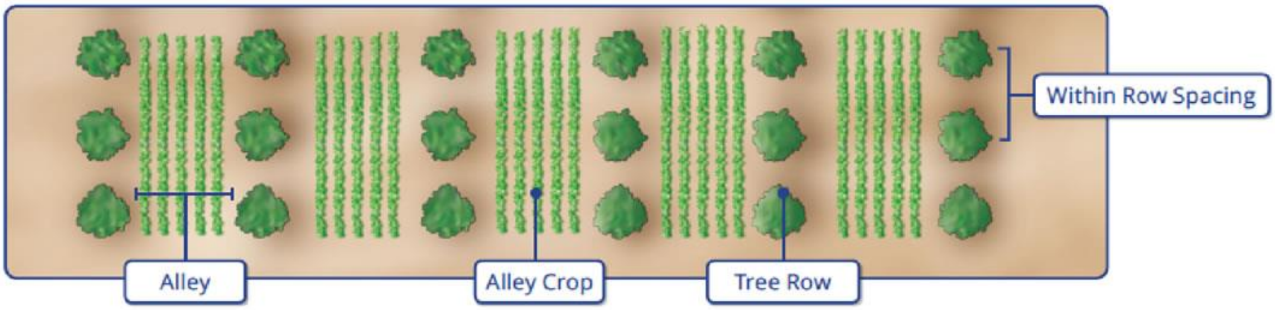

Figure 1.7. Different cropping systems: alley, alley crop, tree row, and within row spacing

Source: (USDA 2018)

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Crops suitable for this practice include mushrooms, ornamental plants, nuts, and medicinal herbs.

Additional ecosystem services of this intensified production is the regular attention in the woods may help to spot and control invasive plants and pests as well as the reduced harvest pressure on wild plant's populations that allows them to be reestablished in other woodlands in the region[13]

Combines trees with forage and livestock production. Silvopasture is the deliberate integration of trees and grazing livestock operations in the same land. These systems are intensively managed for both forest products and forage, providing both short- and long-term income sources.

[13] https://www.fs.usda.gov/

Well-managed silvopastures employ agronomic principals, typically including introduced or native pasture grasses, fertilization and nitrogen-fixing legumes, and rotational grazing systems that employ short grazing periods that maximize vegetative plant's growth and harvest. The annual grazing income helps the tree operation of cash flow, while the tree crop matures and creates easy access if and when the trees or tree products are harvested. While these systems can require a number of management activities, the benefits can make it worthwhile.
The plants for bioenergy production or honey production may be added too.

1.3.2. Identification of barriers for technology

It is important to be mentioned that barrier analysis was conducted in partnership with the FAO under the GEF project implementation FAO GEF, 2019). It contributed to develop the list of barriers in the result of the discussion held during the four meetings of the working group in the four oblasts of Ukraine: Kherson, Kharkiv, Mykolaiv, Kyiv. The experts from the relevant government authorities, farmers, FAO expert on shelterbelt inventory and agroforestry as well as experts of Institute of forestry from in Kharkiv were involved. Annex III A.

A number of barriers to the further development of Agroforestry practices (shelterbelt reconstruction) have been preliminary identified and listed in the random order on the basis of the legislative base and literature review, open internet resources and interviewing of the relevant representatives.

Long list of the barriers for the agroforestry technology implementation and diffusion:

1. The unclear legislative mechanism of shelterbelt management
2. Lack of state financial supporting mechanisms
3. Shortage in the supply of planting material that occurs on a regional basis
4. Long-term pay-off period
5. Insufficient access to the innovative methodologies for carrying out shelterbelts inventory
6. The low priority of CC adaptation measures
7. The absence of clear guidance for shelterbelt management: from land right acceptance to the planting and maintenance.
8. Lack of relevant study programs
9. Inefficient Extension services
10. Lack of systematical research
11. The absence of relevant data and information
12. Insufficient capacity to protect shelterbelt's parcels by their owners
13. The high cost of implementation and maintenance
14. Lack of the capacity to conduct the shelterbelt inventory
15. Lack of capacity to develop the planting project documents
16. The cost of implementation and maintenance
17. Loss of crop yields from the field depressive zone
18. Corruption caused by the existent shelterbelt protection regulation
19. Destroying shelterbelts for firewood
20. The insufficient level of energy supply's diversification

In the next step, barriers were screened to their significance following the WG meeting held in Kyiv-Kharkiv, 9th December, 2019 (Annex V). As a result, a shortlist of the essential barriers for the technology transfer and diffusion were developed (Table 1.9.). Moreover, barriers were classified by the recommended categories. The barriers recognized as non-essential were discarded and ignored subsequently.

Table 1.9. Short List of the Barriers Screening for Agroforestry practices (shelterbelt reconstruction)

#	Barrier	Barrier category	Influence quantity
1	Unclear legislative mechanism of shelterbelt management	Legal and regulatory	CRUCIAL
2	SPR related corruption	Legal and regulatory	CRUCIAL
8	The low priority of CC adaptation measures on the government level	Legal and regulatory	IMPORTANT
3	Lack of state financial supporting mechanisms	Legal and regulatory	IMPORTANT
4	Insufficient capacity to protect the shelterbelts parcels	Economic and financial	IMPORTANT
5	Long-term pay-off period	Economic and financial	IMPORTANT
6	The high cost of (agroforestry practice) implementation and maintenance	Economic and financial	LOW IMPORTANT
7	Shortage in the supply of planting material	Technical	LOW IMPORTANT
8	Lack of the capacity to conduct the shelterbelt inventory	Technical	LOW IMPORTANT
9	Lack of capacity to develop the PPD	Institutional and organizational capacity	LOW IMPORTANT
10	The absence of clear guidance for shelterbelt management	Information and awareness	EASY STARTER
11	Limited knowledge on technology implementation	Information and awareness	EASY STARTER
12	Loss of crop yields from the field depressive zone due to lack of knowledge how to solve this problem	Information and awareness	EASY STARTER

Then barriers were decomposed, and the simplified problem tree was developed (Annex I A, Figure AI- 05).

1.3.2.1. Economic and financial barriers

The two categories of the economic barriers were distinguished in the process of the WG consultation:

- important: "Insufficient capacity to protect the shelterbelts parcels" and "Long-term pay-off period";
- low important: "The high cost of (agroforestry practice) implementation and maintenance".

Insufficient capacity to protect the shelterbelts parcels. Due to the uncertain situation with ownership rights on shelterbelts as well as the absence of the appropriate data correct amount and conditions of shelterbelt by the regions, there is no specific mechanism of shelterbelt protection. Tentatively, over 10,000 hectares of forest strips in the fields have been permanently lost due to illegal logging in 2019. The community of village councils and shelterbelt's owners (if any) should protect shelterbelts themselves. Shelterbelt's defense increases the maintenance cost and demotivates end-users to apply agroforestry practice.

Long-term pay-off period. In Ukraine, the pay-off period of the field protection agroforestry practice is 12-15 years (GCP/UKR/004/GFF). This fact significantly decreases the motivation of farmers and other end-users to apply technology. There is also a lack of awareness of the best existent experience on agroforestry practices with additional economic efficiency.

The high cost of (agroforestry practice) implementation and maintenance. The technology requires the following significant capital expenditures in the implementation phase:
1. Carrying out inventory and land management works. This work can be provided by the licensable specialists in land management. The average cost of land inventory – $ 50 US/ha. The land inventory might be ordered by both the local communities and farmers (producers).

Land inventory is carried out in accordance with the Decree of the Cabinet of Ministers of Ukraine of June 5th, 2019 No. 476 "On Approving the Procedure for Land Inventory and the Recognition of Some Decisions of the Cabinet of Ministers of Ukraine" (GOV UA, 2019).

2. The inventory of the shelterbelt's technical conditions determining their physical characteristics, assess the afforestation status of plantations and provide for the possibility of further development of a set of measures for the care of shelterbelts aimed at extending the lifecycle of logging—forest management fieldwork. The range of the shelterbelt inventory average cost between $ 30 -130 US/ha. The cost depends on the region and accessibility authorized service providers.

3. Design planting project documents, permits, and environmental impact assessment, if required. The objectives of the developing planting project are (i) to identify the proper type of shelterbelt in accordance with local environment-specific; (ii) to select relevant plant species; (iii) to develop technological maps. The total average cost of capital expenditures is about $ 1 200 per hectare.

4. The establishment (reconstruction) of shelterbelt for field protection. The cost per hectares depends on the planting materials and technological operation and can range from the $ 1000 US (Annex IV A, Table IV A-01) to $ 2000 US.

Operating expenses to support the operation of shelterbelts include expenses on seeds, fuel and lubricants, water, plant protection agents, labor, equipment rental, etc. The average level of operating expenses can vary from 70 to 1000 US dollars per hectare, depending on the year of laying the shelterbelt. The first two years will require more significant support.

Despite the competitive high capital and maintenance cost, consumers are ready to apply agroforestry practice and pay. Partly it is possible as they have some basic capacity to do this (the rest of the shelterbelt in place; having access to the budget money; and etc.). Secondly, they recognize agroforestry as the most efficient tool to protect fields from soil erosion and dust storms, especially in the arid regions.

1.3.2.2. Non-financial barriers

The unclear legislative mechanism of shelterbelt management and Corruption caused by SPR.
As a result of the land reform in the mid-1990s, farmland has been privatized (cut in individually owned land parcels). Protective plantings, including field protective shelterbelt, that had been once used by collective farms, eventually fell out of the economic turnover. They were not subject to parcelling and remained parts of reserve or general use’s funds being situated outside of the residential areas. It caused the uncertain and unclear situation around the shelterbelt ownership rights and management.

Since that time, shelterbelts have not been guarded, maintained and renovated, which resulted in total or partial deterioration of shelterbelt and losing their protective qualities.

Shelterbelts are frequently turned into the household, industrial and agricultural waste landfills, weed plantations.

They are affected by fire that decreasing the vegetation or, worse, lead to their extinction. The shelterbelt is also illegally chopped by locals for their own needs. They should be protected by the local defence authorities, but it does not happen due to the high level of corruption in the authority.

In the course of decentralization reform that has been underway since 2014, the agricultural land beyond the limits of residential areas is being taken over on the balance of amalgamated territorial communities. This process started in February, 2018 while on July 10, 2018, the law GOV UA, 2018, and took effect on January 1, 2019[14].

The amalgamated territorial communities undertake all the shelterbelts' ownership, usage, and disposal rights as a result of the reform. They will also be responsible to maintain the shelterbelt's conditions.
However, there is a need to develop legal mechanisms for land transfer and forest inventory at regional levels.

The low priority of CC adaptation measures. The low interest of the relevant top-government to CC adaptation in agriculture may be observed. The situation like this does not stimulate the development of the state financial supporting mechanism and/or overcome the lack of relevant institutional capacity.

Lack of state financial supporting mechanisms. There is no relevant state support to develop agroforestry practices as well as shelterbelt reconstruction and maintenance. Thus, this barrier can be classified as important especially considering the long term pay-off period, lack of institutional capacity and high cost of the shelterbelt protection.

Shortage in the supply of planting material. On the one hand, the Ukrainian market has enough developed institutional potential and infrastructure to satisfy supply. A comparison of the demand with the supply of cultivated seedlings shows a significant (almost 1.5 times) overproduction of regular planting material in nurseries. In 2013, over 46 million seedlings were grown: the share of seedlings of common pine is 84%; common oak - 8%; European spruce - 4%; red oak - 2%; European larch - 0.2%; and blackberry aronia - 0.4%. (Kaidyk, 2009). There are around 350 nurseries in the structure of the state forest enterprises. Moreover, the private business breeding plant for species business, private nurseries for decorative, fruit, nut trees and other plants are highly developed.

Lack of the capacity to conduct the shelterbelt inventory and Lack of capacity to develop the PPD. In Ukraine, the regulatory and methodological issues of forest inventory are regulated by the Cabinet of Ministers of Ukraine (GOV UA 2012) and set out in the "Guidelines for Timber and Reclamation Management of Protected Forest Lines in strips of canals, railways, roads (GOV UA (A) 2012).

[14] In view of the fact that decentralization reform has been at its final stage, 1002 amalgamated territorial communities have been formed, which covers half of the Ukrainian territory.

The process of inventory of shelterbelts is divided into several stages (Figure 1.8.), which has to be carried out in accordance with the requirements of the abovementioned regulatory documents. Potential customers are regional authorities, amalgamated territorial communities (ATC), rural communities, big agro producers, public companies, farmers, other shelterbelt owners.

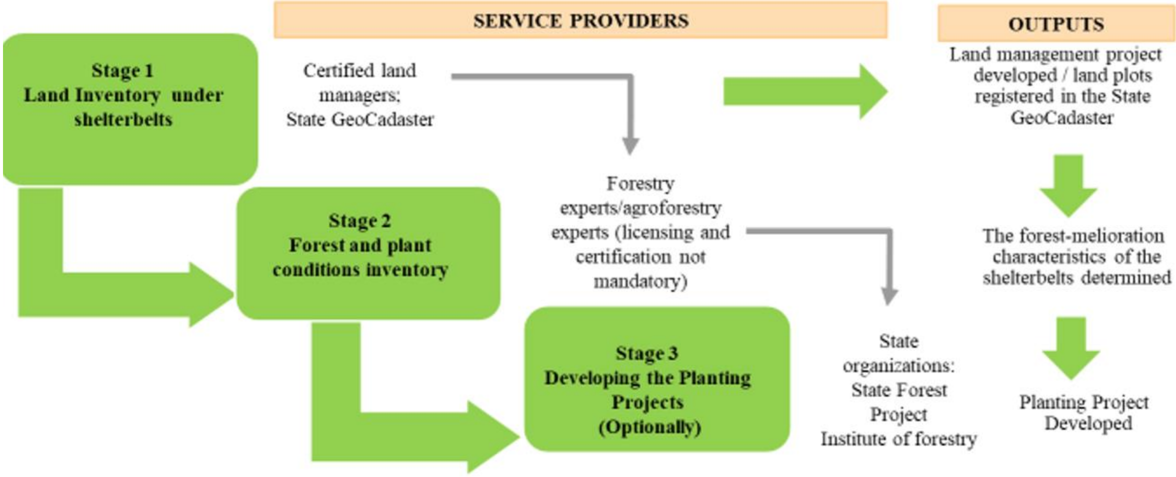


Figure 1.8. Stages, service providers and outputs of shelterbelt inventory process
Source: (FAO GEF, 2019)

However, there is a strong shortage of service providers who are able to satisfy all needs. Following the experts' points, there are only two official organizations and around 10-15 relevant experts that are able to develop technical projects for shelterbelts planting refer to nowadays requirements on stage three. In the scale of Ukraine, the first stage of shelterbelt inventory may be conducted, but the second one will take time due to the poor capacity of human resource.

Absence of clear guidance for shelterbelt management. The agroforestry practices have not been in the focus of the political or business interests since the beginning in the 90th. Certainly, their clear step by step guide for shelterbelt management was not developed and registered officially. However, this barrier may be easily overcome due to materials and documents have been developed by the research institutes and under the international technical capacity projects.

Limited knowledge on technology implementation and Lost of crop yields from the field depressive zone. The potential end-users of a shelterbelt, such as farmers, are not motivated to develop agroforestry practice because of the uncertain regulation of ownership rights as well as due to lack of technical knowledge and skills. Thus, one of the leading farmer's concerns is that the productivity of the crop could be decreased in the depressive zone caused by the shadow from the shelterbelt. However, this problem could be easily fixed, if a variety of plants and technology were combined. Following the experts' opinion, there is not a lack of proper techniques; instead, there are problems in the increasing awareness and the appropriate transfer of technology.

The problem tree on the Agroforestry practices (shelterbelt reconstruction) technology is presented in Annex I A, Figure IA-05.

1.3.3.1 Economic and financial measures

The economic measures depend on the increasing agroforestry practice efficiency through the extension value add chains.

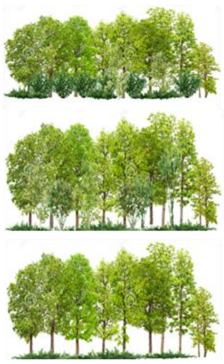
Agroforestry can be defined as a sustainable land resource management system in the multifunctional landscape that diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. In particular, agroforestry is crucial to smallholder farmers and other rural people, because it can enhance their food supply, income, and health (Lasco et al. 2011). Following this statement and experts' opinion (Annex VII), increasing the economic efficiency of the shelterbelt can be a real tool to motivate consumers to order to develop and scale up agroforestry practices.

Approximate cost of the shelterbelt construction in the Steppe zone in Ukraine presented in Annex IV A, Table IV A-01 is based on the technological map for the two years cycle.

Increasing the economic efficiency of shelterbelt depends on the type of agroforestry practice, it would be selected and developed properly to the landscape and environment condition. Thus, potentially end users can increase their profitability due to:

- increasing crop's yield by 20-36% depends on the type of shelterbelt;
- reducing the risk of losses due to adverse climatic conditions by diversifying production activities and the concomitant production of additional products;
- the possibility of reducing the cost of crop production by reducing moistening costs;
- increasing the likelihood of maintaining the base yield in dramatic climatic conditions.

The additional economic efficiency per ha was calculated in the Figure 1.9.



Shelterbelt construction	Yield increasing, %	**Potential income, US $/ha**
Dense	20 – 23	**+ 170**
Openwork	23 – 36	**+ 250**
Ventilated	22 – 33	**+ 220**

Figure 1.9. Potential profitability of shelterbelt by the construction type (nationally defined)
Source: designed by N.Vysotska , 2020.

,Moreover, extension can be provided with economy efficient agroforestry practice such as Alley Cropping, Forest Farming and/or Silvopastore.

Another steps in value add are mixing the agroforestry practice to increase the efficient use of the depressive zones in the fields.

1.3.3.2. Non-financial measures

The enabling non-financial measures which can be developed under existing national environment presented in the Table 1.10.

Table 1.10. Nonfinancial Enabling Measures for Agroforestry practices (shelterbelt reconstruction)

#	Barrier	Enabling Measures
1	Unclear legislative mechanism of	1. Land use purpose changing. Reducing the area of arable land to 37-41% of the country's territory by removing more than 3 degrees from the arable land, lands of water protection

	shelterbelt management	zones, degraded, unproductive and contaminated agricultural land by 2025 (GOV UA, 2003); 2. Improving land management under the shelterbelt (GOV UA (C); 3. The incorporation of the rule of shelterbelt planting and to maintain as well as planting projects into the legislation mechanism of the shelterbelt management; 4. Developing the lease agreements (emphyteusis) of shelterbelt for the different type of consumers, servitude should be sought.
2	Corruption caused by SPR	1. Increasing the public control role in village communities to define the shelterbelt; 2. The automation of the process of issuing permits to forestry tickets (forestry maintaining activities); 3. Developing the permanent monitoring system of the shelterbelt conditions; 4. The creation of the local inspections to define the activities for shelterbelt's maintenance.
3	Lack of state financial supporting mechanisms	1. The acceptance of the draft Rules for the maintenance and preservation of forest protection strips located in agricultural lands (GOV UA (A), 2019); 2. Unified regulation to manage farmlands and shelterbelts; 3. Incorporation to the global system of climate subventions; 4. Developing the market of climate action incentive payments; 5. The optimization of the approach in order to redistribute the budget money such as the "ecological" funds.
4	Shortage in the supply of planting material	1. Local public companies equipped to plant shelterbelts and wood residue recycling; 2. Increasing the amounts of container nurseries to produce ball-rooted planting stock; 3. State nursery technical modernization; 4. The application of a variety of plants resistant to climates change such as plants and crops in order to produce bioenergy from biomass; nuts etc.
5	The low priority of CC adaptation measures	1. Developing the sub-section for scaling up the agroforestry practice as a part of the Climate Change mitigation and adaptation strategy; 2. Conducting a study of a quantitative assessment of climate change risks by sub-sector and regions on agroforestry; 3. The economic assessment of the climate change's impacts on soils, water reservoirs, and biodiversity, improving the productivity of land and water resources.
6	Lack of the capacity to conduct the shelterbelt inventory	1. The extension of the remote sensing application for shelterbelt inventory; 2. Launching the practical training for professionals; 3. The modification of the academic study programs.
7	Lack of capacity to develop the PPD	1. The creation of an electronic catalog of seedling and nurseries including climate resilience and economically efficient species; 2. Launching professional training.

8	The absence of clear guidance for shelterbelt management	1. The elaboration of the best agroforestry practice guideline; 2. Developing the step-by-step guideline of shelterbelt inventory for farmers and rural communities.
9	Limited knowledge on technology implementation	1. Development and popularization of the educational web-channel for technology promotion; 2. The extension of the master program in agronomy with the proposed technology and developing on-line course available for all relevant Universities and Institutes; 3. Involving farmers and leading experts as lecturers; 4. Strong cooperation between farmers and academy; 5. Creating the open base for the best practices and success stories.
10	The loss of crop yields from the field depressive zone	1. Canopy management; 2. Haymaking or growing medicinal herbaceous plants and melliferous on the depressed areas.

The objectives expected in the result of some measures implementation were analyzed and presented in Figure 1.10.

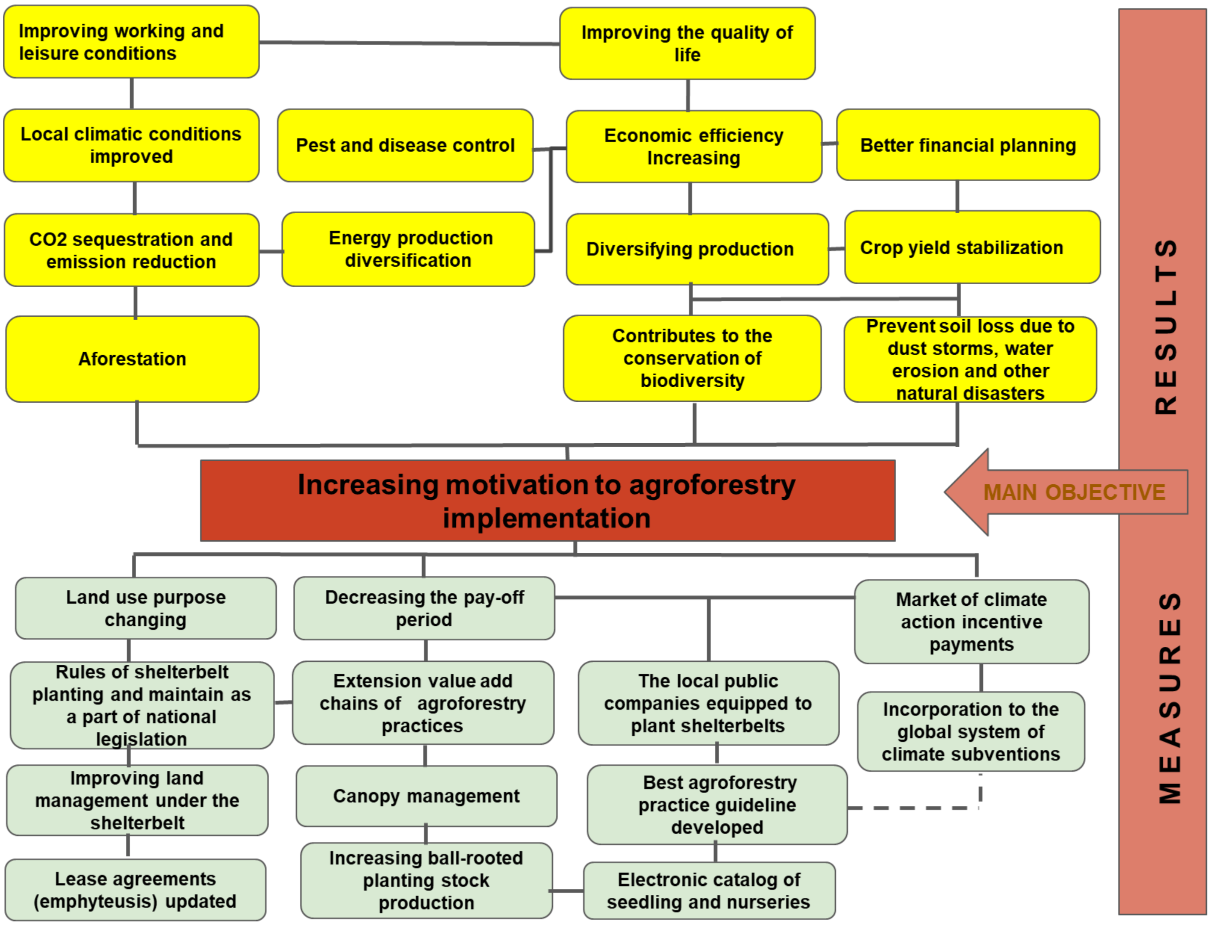


Figure 1.10. Simplified Objective Tree: Agroforestry practices (shelterbelt reconstruction)

1.4. Barrier analysis and possible enabling measures - Integrated Pest and Disease Management (biodegradable mulch film)

1.4.1 The general description of technology

The spread of atypical or rapid development of typical pests, weeds and diseases are some of the most important challenges, the crop production is facing in adapting to climate change. Chemical plant's protection products (PPPs or pesticides) have rapid but extremely short-term efficiency due to increased resistance to their action. In addition, pesticides also impose a serious negative impact on human health and the environment. Biologizing crop cultivation processes involves a variety of strategies to partially replace or abandon the use of chemical plant's protection products. The use of such approaches as mulching with the use of biodegradable films and the use of biologically active pesticides has the best performance (FAO GEF, 2017) in terms of increasing yields and combating unpredictable weather influences.

Mulching with the use of biodegradable films improves water retention in soil, forms a protective barrier from the germination of weed's seeds and a thermal barrier[15]. The biodegradable film is made from organic components of plant and animal origin and therefore can be destroyed by chemical reactions under the influence of microorganisms, the sun, and oxygen. It decomposes into water, carbon dioxide and is absorbed by soil microorganisms, becoming one of the components of the humus layer. Decomposition and biodegradation occur by the biological action of living microorganisms that naturally exist in any ecosystem. According to its technical characteristics, the film can have an average diameter of 8 to 80 microns, which directly affects its life cycle from 3 to 24 months and a width of 50 to 280 cm. Available types of film - transparent, black and color that have different technological and species designations. The film can be stacked either using a special film-laying machine or manually. The Biodegradable Mulch Film (BMF) laying process does not require significant changes in technological maps. For a large amount of cultivated area, it is advisable to purchase specialized equipment such as bed-maker and mulching film layer (as in the process of mulching with conventional plastics).

However, as a technological advantage is that sowing seeds using a BMF can be done by the application of existing seeding equipment and it is still possible to use those seeders for the traditional sowing without films. Therefore, it does not entail significant costs for the design, production and purchase of new sowing machines. The biodegradable film is laid during sowing.

Arable land potential - there are no significant restrictions; geographical coverage - all agro-climatic zones of Ukraine, especially zones with a moisture deficit. Potential users – all types of farms.

Technological potential - there is a complete provision of necessary equipment by international and national manufacturers, satisfactory provision of BMF. The market is represented by several BMF producers, both international and national. Hence, an international company Ginegar manufactures Mulch More BMFs. It is slightly lower in price, however of appropriate quality, is the national BMFs produced by the joint company IMMER Group (IMMER Ukrplastic, IMMER Digital and IMMER Design Studio). The IMMER Group provides an entire manufacturing cycle of flexible packaging materials and uses a wide variety of crop production technologies. To date, BMFs are mainly used in greenhouse complexes and planting vegetables in the southern regions. However, farmers still prefer plastic counterparts over BMFs, due to the higher purchase price of the BMFs. However, it is often not taken into account that the economic cost of conventional polythene, in addition to the price of the product, also includes the cost of disposal and use.

[15] Technologies are registered on the Climatetechwiki platform. ttp://www.climatetechwiki.org/technology-information.

In this sense, biodegradable polymers are better, since the renewable resources required for its production are more profitable. It is also important to note that the high cost of the material is a temporary phenomenon, until biopolymers are to be produced on a large scale.

The BFM application is the most efficient for vegetable production in general and particularly for tomato. Tomato is the leader of vegetable production in the world. However, during the recent decade, a significant shortage of tomato production has been observed in Ukraine. The analysis of time series data of the cultivated land under vegetables, 2010 - 2019 showed that the largest shortage occurred in the area under tomato production (-14.9 thousand ha), the second and third place under the cabbage (12,5 thousand ha) and onion (12 thousand ha), correspondingly.

Meanwhile, Ukraine imported 58.55 thousand tons of tomato worth $ 37.25 million in 2019 (State Fiscal Service of Ukraine, 2019). At the same time, the export of these products from Ukraine in the reporting period amounted to 5.99 thousand tons in the amount of $ 3.83 million. Thus, the import of tomato into Ukraine is 9.3 times higher than export. In general, during the 2018/19 marketing year, vegetable imports to Ukraine reached 264 thousand tons, which significantly exceeded the previous record, which lasted 9 years.

In a row with the shortage of the tomato processing sector in Ukraine, the unfavorable weather conditions also accelerate the tomato cultivation's reductions. Thus, in 2019, Transcarpathian (Western part of Ukrain) farms lost part of the harvest due to massive flooding of greenhouses. In the South, in the season of harvesting soil, tomato was delayed, and constant weather changes contribute to the spread of disease and, accordingly, adversely affect the yield.

In regard, the BFM application has a set of the direct and indirect benefits to generally produce vegetables and tomato, in particular:

The direct economic benefits:

- increase in yield by an average of 30% for all commodity groups of agricultural crops, and for some up to 75%;
- the reduction of water, fertilizers and PPPs costs by an average of up to 40% for all commodity groups of agricultural crops, and for some by 3 times;
- increasing the export potential of agricultural products through quality improvement.

In the case of tomato production, there are three types of cultivation able to deliver the same yield: cultivation under drip irrigation, greenhouse production, and BFM. However, cost and profitability are different for each technology (Table 1.11.).

Table 1.11. The economic efficiency of tomato production by the technology

Item/Cultivation technology	Irrigation	BFM	Green House
Labor cost, $/ha	1767	1202	1856
Seeds, $/ha	865	421	865
Fertilizer, $/ha	1514	615	1296
Pesticides, $/ha	296	119	320
Fuel, $/ha	140	174	14
Energy (electricity, gas), $/ha			427
Irrigation system	918		
Water, $	180	62	143

BFM, $/ha		504	
Plastic film, S/ha			381
Utilization $/ha	123		257
Depreciation, $/ha	136	42	167
land lease, $/ha	17	17	17
Other expenses, S/ha	1207	1002	2117
Cost, ha	7163	4158	7860
Water, m3	2157	740	1720
Yield, t/ha	60	60	60
Price, $/kg	0.7	2	2
Income, $	42000	120000	120000
Profitability, $[16]	34837	115842	112140

Source: own computation based on the data obtained (Sabluk, 2009)

Mainly, profitability defined by the early harvesting time and high price on tomato.
The co-benefits:

- the optimization of water balance and water quality in the region;
- significant increase in soil organic matter content and humus due to BMF decomposition to organic compounds, increase in the micellar mass, reduce in the soil salinity, increase in the accumulation of oxygen in the soil;
- improving the agrochemical inputs in the soil in a condition of sufficient moisture, the improved use of plant nutrients from mineral fertilizers, especially phosphorus (particularly at moderate application doses) due to the localization of fertilizers and the root system in the most biologically active surface layer.

Climate change’s adaptation potential can be demonstrated by the following:

- temperature control;
- microclimate modification in plant and soil environments;
- heat preservation and soil temperature increase, photosynthesis improvement;
- control of humidity level;
- moisture protection or water saving;
- to control the spread of weeds and pests;
- to attract or repel the pests - optical pest control methods;
- adaptation to agro-climatic season’s shifts.

The strength of combating climate change takes place by means of:

- reducing CO2 emissions into the atmosphere by reducing input costs for the use of mineral fertilizers and herbicides;
- CO2 sequestration by improving the development of the plant's root system.

Technology application for restrictions and caveats. The main restrictions on the use of the technology is a violation or deficiency of factors determining the complete biodegradation of the polymer material, such as:

- The deficiency of microorganisms acting selectively on polymeric materials;
- minimum moisture content;
- other relevant environmental conditions (temperature, pressure, humidity in the liquid and vapor phases, the type and concentration of salts, the presence or absence of oxygen, etc.).
- If one of these elements is missing, the biodegradation does not occur.

[16] Profitability was counts before tax and without storage, transportation, natural loss costs.

- Moreover, the use of bioplastics may be limited in those locations, where the risk of their biodeterioration is high. Biodeterioration can be caused by the following factors:
- by macroorganisms (animals, higher plants);
- by microorganisms (bacteria, fungi). The most aggressive of these are mold fungi such as Aspergillus, Penicillium, Trichoderma.

1.4.2. Identification of barriers for technology

A number of barriers to the further development of Integrated Pest and Disease Management (biodegradable film) for growing major crops have been preliminary listed in the random order on the basis of the literature review, open internet resources, interviewing of the relevant representatives of the academy, government, public, and business. The technology of biodegradable films is classified as a consumer goods.

Long-list of barriers for the for technology - Integrated Pest and Disease Management

1. Lack of raw materials and technologies for BMF production in Ukraine;
2. Lack of appropriate methodologies for soil condition survey investigating the possibility of BMF application;
3. Low level of technology promotion in the country;
4. Lack of training on the use of this technology.
5. Lack of finance
6. Competitively high price of BMF
7. Low level of awareness
8. The inefficient capacity of Extension services
9. Poor developed market;
10. Lack of manufactures, BMF producers
11. The insufficient number of service providers and BMF retailers
12. Low interest to innovative sustainable business models
13. Limited supply
14. Insufficient demand
15. Lack of understanding of the significant benefits of using BMF
16. The absence of regulation on plastic film application
17. Lack of penalty and control on the improper plastic material disposal
18. The insufficient level of advertising
19. The low priority of CC adaptation measures

The barriers were reviewed and screened according to their significance by experts, mainly producers and consumers, as well as other significant players in agricultural markets[17]. As a result, shortlist of the crucial barriers for the transfer and diffusion was developed (Table 1.12.). Moreover, barriers were classified by the recommended categories. The barriers recognized as non-essential were discarded and ignored subsequently.

Table 1.12. Short List of barriers Screening for IPDM (biodegradable mulch film)

#	Barrier	Barrier category	Influence quantity
1	Lack of raw materials and technologies for BMF to arrange domestic production	Economic and financial	CRUCIAL

[17] Consider the fact that technology classified as Consumer Goods the BMF producers and consumers were identified as a target audience to barriers screening. The task-force meeting was not held.

2	Lack of manufactures, BMF producers	Economic and financial	CRUCIAL
3	Low priority of CC adaptation measures	Legal and regulatory	IMPORTANT
4	Low interest to innovative sustainable business models	Market conditions	IMPORTANT
5	Inefficient capacity of Extension services	Institutional and organizational capacity	IMPORTANT
6	Competitively high price of BMF	Economic and financial	LOW IMPORTANT
7	The absence of regulation on plastic film application	Legal and regulatory	LOW IMPORTANT
8	Lack of understanding of the significant benefits of using BMF	Information and awareness	EASY STARTER

Then the barriers were decomposed, and the simplified problem tree was developed (Annex IA. Figure AI- 06)

1.4.2.1. Economic and financial barriers

The economic and financial barriers play a crucial role in the scaling of the biodegradable film in the Ukrainian market.

Mainly this is associated with the type of technology. As a consumption good, the success with the technology distribution is caused by the market mechanism rather than regulation or political issues.

Lack of raw materials and technologies for BMF production in Ukraine. There is no technical capacity for deep recycling or another source to produce the feedstock for BMFs. In this case, feedstock should be bought abroad which directly influences a price.

Lack of manufactures, BMF producers. Low demand for BMFs and lack of CC policy results in a production monopoly. Due to low demand and lack of political motivation, potential producers are not interested in investing money for developing the domestic manufacturing BMF production. Developing technology requires high capital investment, thus producers need cheap financial resources. However, due to low market liquidity, they are not looking for them.

Due to BMF's monopoly, price is higher in comparison with their plastic substitutions. Moreover, there is no other motivation to switch to BMFs such as regulation, control, limitation and penalties for plastic applying and utilization.

The competitively high price of BMF was defined as a barrier of low importance as once farmers would realize benefits from BMF's application they would be ready to cover these cost's differences.

1.4.2.2. Non-financial barriers

The low priority of CC adaptation measures. The low priority of CC adaptation measures in the country impacts negatively both on motivation to develop the market and switch to the innovative sustainable business models. Agricultural producers are mainly interested in getting short time profit rather than invest in natural resource development. The barrier was identified as important due to the level of impact on technology's development as well as challenging being overcome.

Low interest to innovative sustainable business models. On one hand, there is an absence of interest to the adaptation of CC policy on agriculture which can be observed. However the low interest in innovative sustainable business models is referring to a lack of knowledge about the external profitability of ecosystem services and increasing assets due to external cost. As usual, agro producers are not familiar with the life cycle assessment of the business process and do not apply it in their production and financial plans.

Inefficient capacity of Extension services. The extensional services are developed in Ukraine. However, due to the low demand and motivation from the government as well as the lack of relevant educational programs and training, adaptation technologies are not the part of their service portfolio

The problem tree on the IPDM technology is presented in Annex I A, Figure IA-06.

1.4.3. Identified measures

1.4.3.1. Economic and financial measures

Table 1.13. Economic and financial enabling measures for IPDM (biodegradable mulch film)

#	Barrier	Enabling Measures
1 2	Lack of raw materials and technologies for BMF to arrange domestic production Lack of manufactures, BMF producers	1. Financial support from the international donor organizations such as the World Bank and EBRR. The amount of the financial support is $ 200 mill doll USA. The support aims at enhancing the competitiveness of agriculture, diversifying, and developing it by improving the effectiveness and targeting of agriculture support policies, improving transparency and efficiency of agricultural land usage; 2. Cross-subsidization under investment into the biotechnology; 3. Subsides from the Ukrainian State Fund of Financial Support[18] up to 500 thousand UAH; 4. Decreasing the production cost through the clustering of farming units; 5. Decreasing the loan ratio; 6. Increasing capacity of the Partial Agricultural Credit Guarantee Fund to decrease the loan ratio; 7. The extension of the state program for partly compensation of purchase expenses on agriculture types of machinery and equipment by the irrigation equipment; 8. Increasing penalties for the improper plastic utilization.
3	Competitively high price of BMF	1. The optimization of the production cycle; 2. The expansion of the advertising company;

[18] https://udf.gov.ua/

	3. Improving the marketing strategy; 4. Optimization of business models; 5. Increasing penalties for the improper plastic utilization.

Growing demand may stimulate to develop the relevant biotechnology and increase numbers of domestic feedstock producers as well as BMF manufacturers.

Increasing supply closely refers to developing a national strategy for climate change's mitigation and adaptation. The production of the feedstock and developing domestic production BMFs do not belong to agriculture production and have limited access to the cheap loan money. However, biotechnology development refers to agriculture can be part of working agenda for such international donors as EBRD or USDA. Moreover, Under the agreement between the Ukrainian government and the European Commission in 2018, Ukrainian cluster organizations can integrate into the European and international cluster communities and receive financial and technical support through the EU Neighborhood Program.

At the same time, supporting the development of clusters, including the agricultural sector, is one of the priorities of regional economic policy. Moreover, developing the agrarian clusters is recognized as one of the most important directions in the development strategies of many regions.

1.4.3.2. Non-financial measures

The enabling measures which can be developed under existing national environment presented in the Table 1.14.

Table 1.14. Non-financial Enabling Measures for IPDM (biodegradable mulch film)

#	Barrier	Enabling Measures
1	Low priority of CC adaptation measures	i. Developing the technology as part of Climate Action Plan of agriculture; ii. Integrated Pest Management including the BMF production should be incorporated as a part of recommended activities under the CC mitigation and adaptation strategy Developing the section for scaling up the agroforestry practice under the Climate Change's mitigation and adaptation strategy; iii. Conducting the economic assessment of the climate change impacts on soils, water reservoirs, and biodiversity, improving the productivity of land and water resources; iv. Developing the national environmental monitoring system.
2	Low interest to innovative sustainable business models	1. Conducting national studies of cost-benefit analysis that compares different pest control technologies with a focus on the ecosystem services on the basis of the life cycle assessment by agro-climatic zones; 2. Developing the enhanced value-added chain for business models for crops with a high amount of starch as a main feedstock of BMF production.

3	Inefficient capacity of Extension services	1. Providing Extension services with guides on the technology implementation by oblast following the climate conditions and technological capacity; 2. Increasing ES capacities through the creation of the common database of the available machinery and equipment and technologies to satisfy a variety of demands; 3. Conducting the relevant pieces of training for the advisers.
4	Absence of regulation on plastic film application	a. Penalties for the use of certain types of plastic from 2022. Draft law № 2051-1 which will stimulate switching use the BMF; b. Prohibition on plastic up to 50 microns thick and oxo folding plastic which will stimulate to increase demand on the BMF.
5	Lack of understanding of the significant benefits of using BMF	i. The creation (and maintenance) of the community of practices for this specific technology Launching the exchange farm-to-farm visit training with the best practice demonstration.

The objectives expected in the result of some measures implementation were analyzed and presented in Figure 1.11.

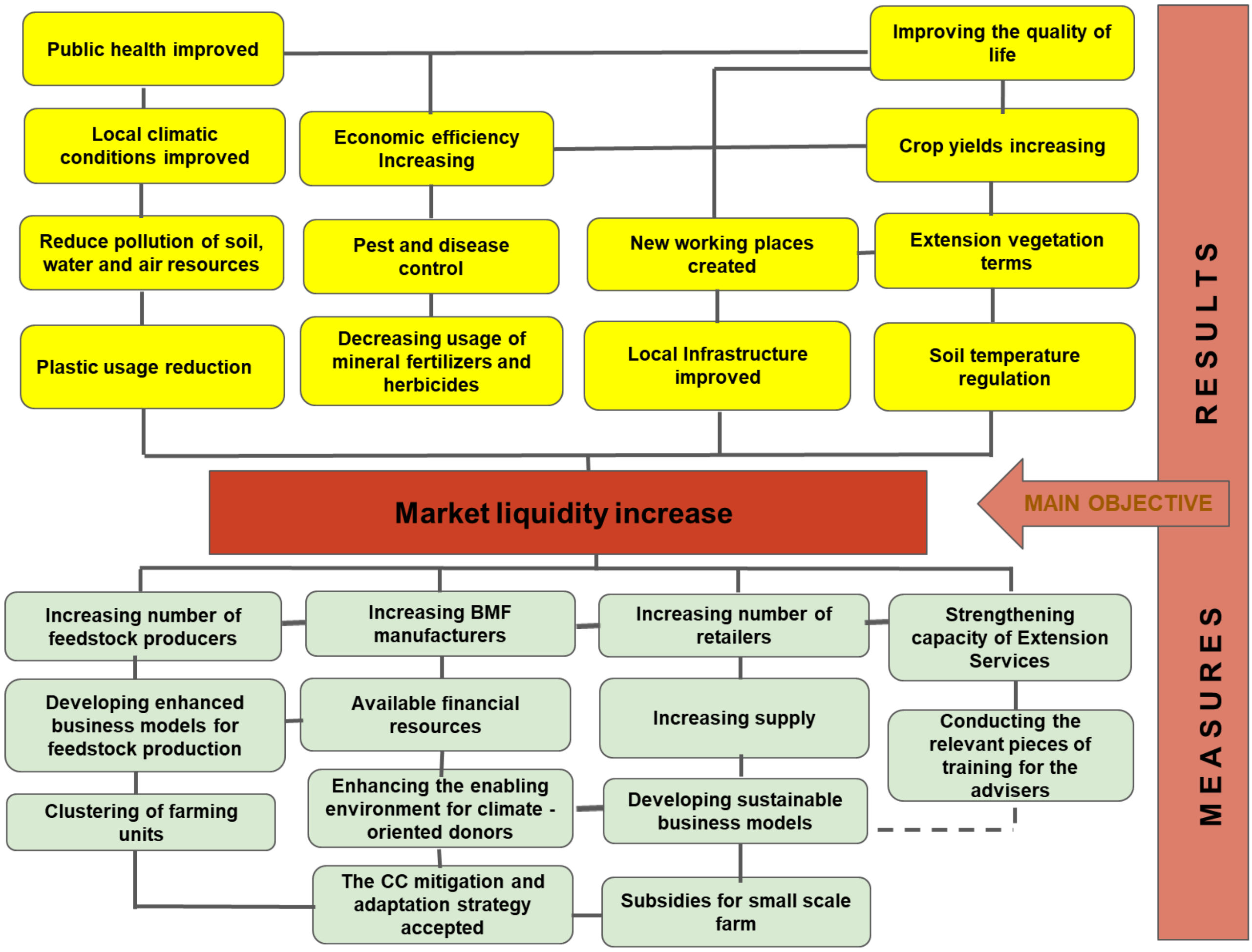


Figure 1.11 Simplified Objective Tree: IPDM (biodegradable mulch film)

1.5. Linkages of the barriers identified in agriculture

The agricultural sector is one of the most ancient and one of the most crucial production sectors for human beings. In other words, that means that human requirement for food is the main drivers to develop technologies and improve agricultural production. With the globalization, processing agriculture has turned to the involvement of global industry and it is defined by the circulation of the global food market. Nowadays the agriculture is not only about food security, it is the key component of economic development and welfare, as it is typical for Ukraine. Thus, three types of national interests can be satisfied through the development of agriculture production: domestic consumption, the economic development of the country (16% is the share of agricultural production in national GDP; 42% of export income is in the country trade balance), and commitments refer to climate change and environment protection.

Furthermore, the eight categories of barriers were recognized particularly for technology transfer and diffusion as well as for sector development in general:

1. Legal and regulatory
2. Economic and financial
3. Institutional and organizational capacity
4. Information and awareness
5. Market conditions
6. Technical
7. Network
8. Human Skills

The categories of different barriers have a different level of affection for technology transfer and diffusion. However, some of the identified barriers has a crucial or important impact on several or even all prioritized technologies. (Table 1.15.)

Table 1.15. The impact of the different barrier category: generic table for all technologies

Barrier Category	DICA	Agroforestry	IPDM BMF
Crucial			
Legal and regulatory			
Economic and financial			
Institutional and organizational capacity			
Important			
Legal and regulatory			
Economic and financial			
Institutional and organizational capacity			
Information and awareness			
Market conditions			
Low important			
Legal and regulatory			
Economic and financial			
Institutional and organizational capacity			
Information and awareness			
Technical			
Easy Starter			
Information and awareness			
Network			
Human Skills			

As can be noticed , the legal and regulatory barriers can be applied for all prioritized technologies. Even more, the absence of the nationally defined CCA policy, lack of effective land market mechanisms, and mechanisms of financial support are common barriers that significantly impact the development of all technologies, while the much specific barriers are character for implementation of the other technologies (e.g. Regulation on shelterbelt establishing and maintenance or Regulation on plastic film application).

With a different level of impact, technology transfer and diffusion are facing economic and financial barriers and despite the the sizeof required investment, the tools of financial support and insurance are insufficiently developed. The Information and awareness barrier also differently impacted the prioritised technologies.

Moreover, it is possible to define the set of barriers referring to specific technologies. For example, the weak market conditions are hindering the BMF technology diffusion while the technological barriers such as lack of machinery and climate-smart agroforestry practice impacted the agroforestry development.

Some barriers are brought to the horizontally integrated linkages between the technologies. It happens, while the barrier for one technology is cooccurring as the restriction for another technological implementation (e.g., poor developed irrigation infrastructure). It is essential to consider horizontally integrated linkages while selecting the stakeholders included in developing the sectoral market maps.

The vertically integrated linkages are based on elaborating the causes/effects relations between the different barriers and barriers' elements for a technology.

Market map for the Agricultural sector is presented in Annex I A, Figures IA -01 – Figure IA-03.

1.6.Enabling framework for overcoming the barriers in agriculture

In accordance with the relationship between the barriers described in the sections above and their horizontally integrated impact on technology development, the following existing incentive measures can be identified to support the dissemination of all priority technologies for adaptation to climate change in the agricultural sector in Ukraine.:

- the developed draft of climate change’s mitigation and adaptation strategy in agriculture;
- the administrative reform of decentralization towards the voluntary association of territorial communities (GOV UA, 2015);
- accepted Land Market Law №2178-10 from March 31.2020, opening the agriculture land market in Ukraine from 2021;
- the signed agreement between the Ministry for development of economy, trade and agriculture (MDETA) and World Bank aimed to develop the agricultural sector in Ukraine. the sought amount of the financial support is $ 200 mill doll USA. The support aims at enhancing the competitiveness of agriculture, diversifying, and developing it by improving the effectiveness and targeting of agriculture support policies, improving the transparency and efficiency of agricultural land usage;
- the partial compensation of interest rates for loans taken in national currency by agricultural and livestock industry enterprises;
- the partial compensation of the cost of seeds supplied by local producers;

- the partial (50%) compensation of the cost of agricultural equipment and machinery produced in Ukraine. The mechanism of receiving state support is approved by the Chamber of Ministers of Ukraine and the list of eligible machinery and equipment is elaborated by a special commission established under the MDETA.
- the partial subsides under advisory services.

Also, the draft strategy on climate change mitigation and adaptation was developed in 2019. The strategy aims at creating the general enabling environment for the climate-smart technology transfer and consists of the next objectives:

1. To improve the institutional structure and interaction mechanism between the governmental authorities on climate change;
2. Climate change's mitigation by emissions reduction and GHG sequestration;
3. 3.To strengthen the research activities and scientific support on climate change in agriculture;
4. Awareness-raising, adjusting the education process and improving the mechanism of knowledge transfer or climate mitigation and adaptation in agriculture;
5. The elaboration and implementation of climate change's adaptation measures at the level of village councils and united village communities;
6. To encourage farmers and agricultural producers to provide climate change's adaptation measures by sub-sectors.

Achieving these objectives linkages to the same stakeholders (Figure 1.12.) which involve into the prioritized technology transfer and diffusion and are marked on the market maps (Annex III A, Annex I A, Figures IA -01 – Figure IA-03).

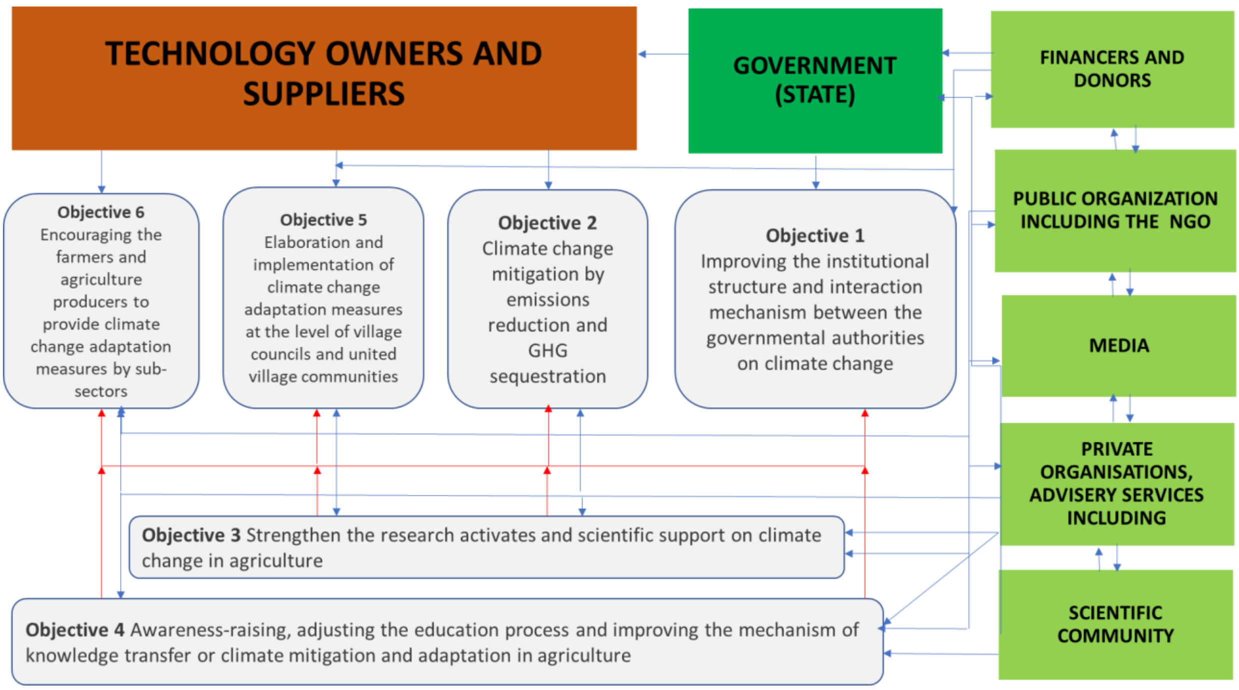


Figure 1.12. The stakeholder mapping by objectives defined in the draft strategy on climate change mitigation and adaptation of agriculture sector

Moreover, there is a set of common enabling measures, whose further development could increase capacity for scaling up of prioritized technologies to reach preliminary defined targets mentioned in section 1.1. and mapped in the technology objective trees:

- Reducing the area of arable land to 37-41% of the country's territory by removing more than 3 degrees from the arable land, lands of water protection zones, degraded, unproductive and contaminated agricultural land by 2025;
- Developing the market of climate action incentive payments;
- The optimization of the approach to redistribute the budget money such as the "ecological" funds;
- To develop and integrate the issues related to climate change into the scope of extension/advisory services. Providing Extension services with guides on the technology implementation by oblast, following the climate conditions and technological capacity;
- Strong cooperation between farmers and academy by using the acting innovative farming and best practices as study objects;
- To conduct a study of a quantitative assessment of climate change's risks by sub-sector and regions on agriculture;
- The economic assessment of the climate change's impacts on soils, water reservoirs, and biodiversity, improving the productivity of land and water resources;
- The creation of the guideline for the technology implementation by oblast following the climate conditions and technological capacity;
- The creation of the common database of the available machinery and equipment and technologies to satisfy a variety of demands;
- To conduct the relevant training for advisers;
- To develop the national environment monitoring system on the basis of the official data;
- Applying the "crowd science" approach in data collection about rapid temperature fluctuation, diseases, plants, and weed spreading;
- To develop the national and international data standards (such as soil classifications, analysis of water quality and so on).

Chapter 2. Water sector

2.1 Preliminary targets for technology transfer and diffusion

The technology prioritized for adaptation in water sector include: 1) Climate-Smart Irrigation, 2) Drought Risk Assessment and Mapping and 3) Flood Risk Assessment and Mapping.

1) **Preliminary targets for Climate-Smart Irrigation technology are:**

- *The restoration of irrigation systems on at least 1.2 million hectares in the areas around reservoirs, major trunk channels with available pumping stations and other equipment. Out of these 1.2 million ha, at least 200 thousand ha are to be located in Kherson, Odesa and Mykolaiv regions and belong to the group of intrafarm irrigation systems (Landlord 2019a) and the remainder 1 million ha are to belong to interfarm irrigation systems. Overall, at least 2.5 million ha of agricultural land in Ukraine is required to be irrigated.*
- *The implementation of Climate-Smart Irrigation technology and output of equipment are required for its elements. This can be achieved, in particular, by providing soft loans to farmers to purchase equipment for the technology, and by introduction of import tax exemptions for importers for the required equipment at early stages of technology deployment.*
- *The development of special funding program aiming to stimulate and support the purchase of equipment and software for the Climate-Smart Irrigation.*

Targets are aligned to the objectives of the national "Irrigation and drainage strategy in Ukraine by 2030". In particular, the Strategy indicates that the available (but not necessarily operational) infrastructure of ameliorative lands reaches 5.5 million ha, comprising of 2.2 million ha with irrigation infrastructure and 3.3 million ha with dewatering infrastructure. The availability of both infrastructure and *water* allow irrigation of 1.5-1.8 million ha and dewatering of 3 million ha during spring flood.

Climate change adaptation potential of Climate-Smart Irrigation:

- prevention of crop loss due to overwatering or underwatering;
- more reasonable and diminished use of water leads to the decreased amount of nutrients reaching water bodies;
- the maximal use of soil moisture;
- the indirect conservation of biodiversity through cleaner water;
- large-scale Climate-Smart Irrigation as water technology is subject to integrated water resource management at the national level (and even at basin) level, contributing to enhanced management of water under the climate change balancing the availability of water supply and irrigation demand.

Economic and environmental benefits of Climate-Smart Irrigation:

- reduced and optimized water consumption;
- the potential creation of new jobs to produce equipment and software;
- the potential activation of banking system that would provide loan for equipment.
-

Mitigation's co-benefit:

- The reduction of CO_2 emissions into the atmosphere as a result of lower electricity consumption, as less water is required to be transported for irrigation.

Due to the favorable combination of temperate climate and fertile soils, Ukraine is one of the main agricultural regions of Eastern Europe, but its territory is exposed to the drought of different intensity and duration every vegetation season (Balabukh, 2016). Strong and widespread general drought is always accompanied by extended anomalies in the atmospheric circulation such as a blocking, which leads to the development of stationary anticyclones and prolonged deficit of precipitation in the impact region (Semenova, 2013).

The increased air temperature and uneven distribution of precipitation, and localized heavy rainfall in the warm season, which does not provide an effective accumulation of moisture in the soil can cause the increased incidence and intensity of drought. The analysis of non-rain periods shows that 4–5 episodes in average are observed annually at all stations. Currently, the amount of non-rain periods is a few less than climatic, but the duration became longer. The average total duration varies from 43-54 days in the west to 56-64 days in the north and increased to 75–96 days in south and east of country (Semenova at al.,2015).

In Ukraine, drought has been observed very frequently in the last three centuries (from 19 to 28 times per century). According to experts, annual crop loss due to adverse weather conditions in Ukraine can be from 10 to 70% and the main cause of this loss is drought. More than 30% of the areas of the best land has a constant shortage of moisture. In the years of severe drought, the negative deviation of the crop's yield from the trend line is up to 500 kg / ha in Ukraine as a whole, in the steppe regions - up to 1000-1500 kg / ha, there are cases of complete loss of the crop.

Studies conducted for the territory of Ukraine about arid phenomena with the use of the SPEI index shows that the maximum number of droughts has been observed in the last thirty years (1981-2010), while the center of maximum recurrence of intense drought was located in the southern and southwestern regions (Chernivtsi, Odesa, and Mykolaiv). The investigation of drought (Khokhlov at al.,2012) showed that the greatest number of manifestations of intense and extreme droughts in Ukraine has been recorded since 1980, when there was a rather intense increase in global air temperature across the globe. The analysis of the spatial distribution over the territory of the study shows that during the period 1951–1980, drought was mainly concentrated in the northeastern regions of the country (Kharkiv, Chernihiv, Sumy), and during 1981–2010 - in the southern and southwestern regions of Ukraine, namely Chernivtsi, Odesa and Mykolaiv regions.

Researcher Semenova I.G. (Semenova, 2015) indicates that there was a tendency to increase the recurrence, intensity and prevalence of seasonal drought after 2000.

2) Drought Risk Assessment and Mapping technology

The climatic modelling of the temperature and humidity regime shows that in the short term, an overall increase in temperature is expected, which will affect all regions of Ukraine and will be particularly intense in the north-eastern region. Rainfall will also increase, but not enough to avoid drought. In both the mild and harsh climatic scenarios, between 2020 and 2050, it is expected that almost every third warm season will be with mild drought throughout the country. During this period, an average of 1 to 3 seasons with moderate and severe drought and no more than 1-2 seasons with extreme drought are forecast. Drought will alternate with wet periods of comparable intensity, with the wettest forecasted between 2034 and 2040, with the most important drought observed in the 2020s and 2040s. The most severe drought, which will reach extreme intensity, will be observed in 2042-2045, and in the south will last until 2050.

According to the RCP2.6 scenario (Semenova I. at al, 2015) seasonal drought in the country are projected to average 48-56% of all years, i.e. almost every second season will be arid. The highest recurrence of drought (over 56%) will be observed in the north-eastern regions and the Carpathian region (over 54% years). According to the RCP8.5 scenario, the overall recurrence of drought in the country is mostly 44-52%, with the highest recurrence (over 52%) was observed in the Azov, Transcarpathia and the north (Kyiv and Chernihiv regions). Minimum seasonal drought (less than 48%) occurs in the southwest of the country - Odesa, Mykolaiv, Vinnitsa regions.

The prolonged droughts with intensity from weak to strong will be observed from 2020 to 2026. The second episode of moderate drought is projected for 2032-2033. The most intense and continuous drought is expected in 2042-2044, when the Standardized Precipitation Index (SPI) values will reach extreme criteria. In the last period from 2046 to 2048, drought will be mostly moderate. The temporal distribution of drought in the hard scenario RCP8.5 is similar to the soft scenario, with two main periods - 2020-2024 and 2042-2045, in which drought is almost continuous and reaches extreme criteria (Semenova, 2015).

Drought is a complex phenomenon caused by a lengthy and significant deficit of precipitation accompanied by elevated air temperature during the warm period of the year resulting in the depletion of water stock through evaporation and transpiration. Accordingly, long-term drought reduces the flow of rivers (hydrological droughts) and surface water supply. Water scarcity and drought have affected most of economic sectors and various ecosystems.

In the last decade, the repetition and the duration of hot weather periods in Ukraine increased significantly (Shevchenko at al., 2013). They have name “heat waves” (HW) and are generally associated with quasistationary anticyclonic circulation anomalies, which produce subsidence, clear skies, warm-air advection and prolonged hot conditions in the near-surface atmosphere. HW has significant impacts on well-being, efficiency and health of humans, which can lead to marked short-term increases of morbidity and mortality, particularly in cities, where most of human beings are living. The total impact of a HW does lead to loss in economic sectors like agriculture, water or forestry and health sector.

Since 1991, the area of dry and very dry zone has increased by 7%. Today it covers almost one third of the territory, including 11.6 million hectares of arable land. At the same time, the area with excessive and sufficient atmospheric humidification has decreased by 10%, occupying only 7.6 million hectares of arable land. Permanent irrigation is required almost at 19 million hectares of arable land, and water management at 4.8 million hectares.

According to forecasts, further climate change will worsen the conditions of natural moisture’s supply. As a result, the role of irrigation and drainage in the production of agricultural products will only increase.

Climate change has a significant effect on the dynamics of agrarian production in Ukraine (Shevchenko at al.,2019), because neither modern technologies nor the latest hybrids provide efficient crop production, when there is lack of water.

Preliminary targets for transfer and diffusion of <u>Drought Risk Assessment and Mapping technology</u> is the creation of modern drought management in Ukraine on the basis of the hydrometeorological service with the involvement of stakeholders from different weather and climate related sectors of the economy and insurances business. The harmonization of interests for all participants of the process will contribute to the stable functioning of the drought management system, its transfer and diffusion in different drought vulnerable regions of Ukraine.

3) Flood Risk Assessment and Mapping

The impact of the harmful effects of flooding is observed in Ukraine on an area of 165,000 km2, which reaches 27% of the territory of Ukraine (Comprehensive program,2006).

Flood-prone regions of Ukraine are located in a. in the environment of different Carpathian inflows in the Dniester, in the area of some Danube tributaries as well Tributaries of the Pripyat (Dnipro) in the northwest of the country.

Within the last 20 years, in Ukraine, significant flood that has led to emergencies have been observed in 1995, 1998, 2001, 2008, 2010. Annual average flood loss in 1995-1998 amounted to more than UAH 900 million, in 1999-2007 more than UAH 1.5 billion, in 2008-2010 - about UAH 6 billion.

Within the scope of various transnational cooperation, some flood-prone river basins have already started, strategies for a cost-efficient flood protection and forecasts as well as early warning systems are to be worked out. This concerns the partial catchment areas of the Danube (Tisza, Siret and Prut) or tributaries of the Dniester.

To reduce flood damage, various technologies for managing water resources are used to reduce surface runoff (use of watertight road coverings, forest plantations, use of water storage basins, wetland, reservoirs); to increase the transport capacity of rivers (construction of bypass channels, deepening or expansion of the river bed), to strengthen dams.

Significant role is played by flood monitoring, flood forecasting, early warning of flood situation development. In the Transcarpathian region, there is an automated information and measurement system for flood forecasting and water resources management in the Tisza River Basin (AIMS Tisza), which was created jointly by the Ukrainian-Hungarian parties and started operation in 2000. To date, the construction of a complex of three flood water reservoirs in the upper reaches of the Dniester (L’viv region) are completed, totaling about 160 million m^3. Such an anti-flood complex will allow during periods of high floods, repeat once every 100 years, to reduce maximum volumes of water, due to the redistribution of runoff by its accumulation in flood reservoirs and polder systems. The water level of the Dniester River at high floods will be reduced by two meters.

To implement the Association Agreement between Ukraine on the one hand and the European Union on the other hand, one of the priorities of the environmental policy of Ukraine is the harmonization of the water legislation of Ukraine with the EU legislation, in particular, with Directive No. 2000/60 / EC "On the establishment of the Community framework for activities in the field of water policy "(Water Framework Directive, WFD) and Directive 2007/60 / EC" On Flood Assessment and Management"(Flood Directive), the main principles of which are the implementation of an integrated basin for water management model and flood management.

The available (but not necessarily operational) infrastructure of ameliorative lands reaches 5.5 million ha, comprising of 2.2 million ha with irrigation infrastructure and 3.3 million ha with dewatering infrastructure. The available infrastructure and available water allow to irrigate 1.5-1.8 million ha and dewatering of 3 million ha during spring flood.

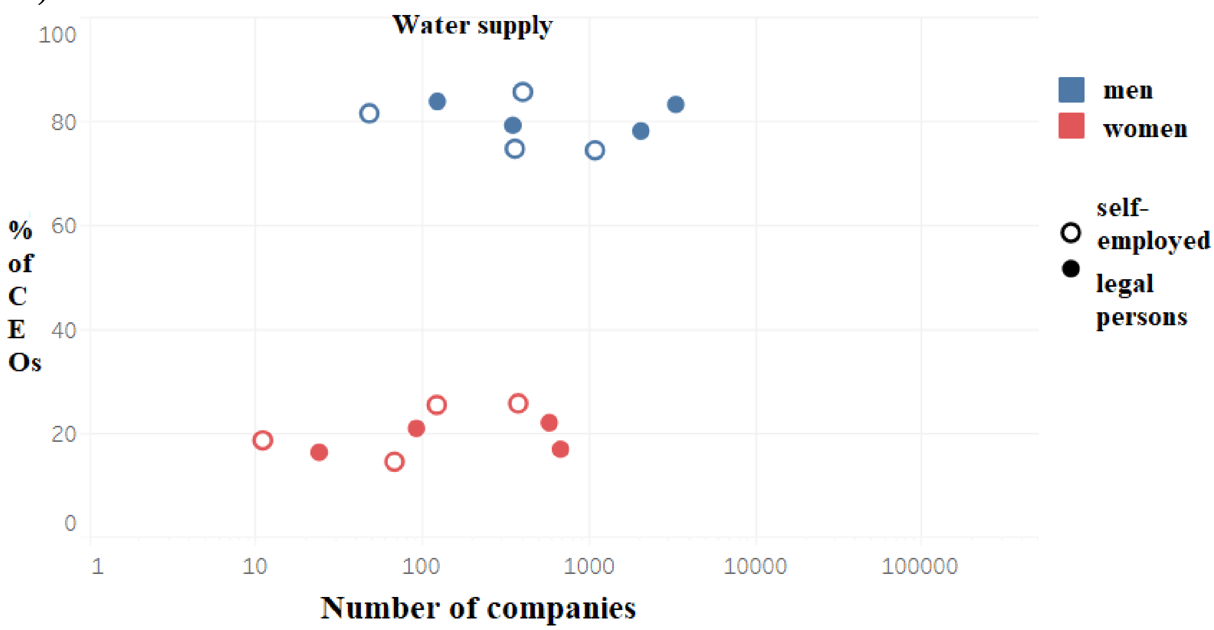
The renovation of available irrigation equipment requires investment of USD 3 billion and would allow irrigation on 1.2 million ha additionally. To implement the Strategy, USD 4 billion are required. The main source of Strategy finance is State budget, so the fulfillment of Strategy is in question.

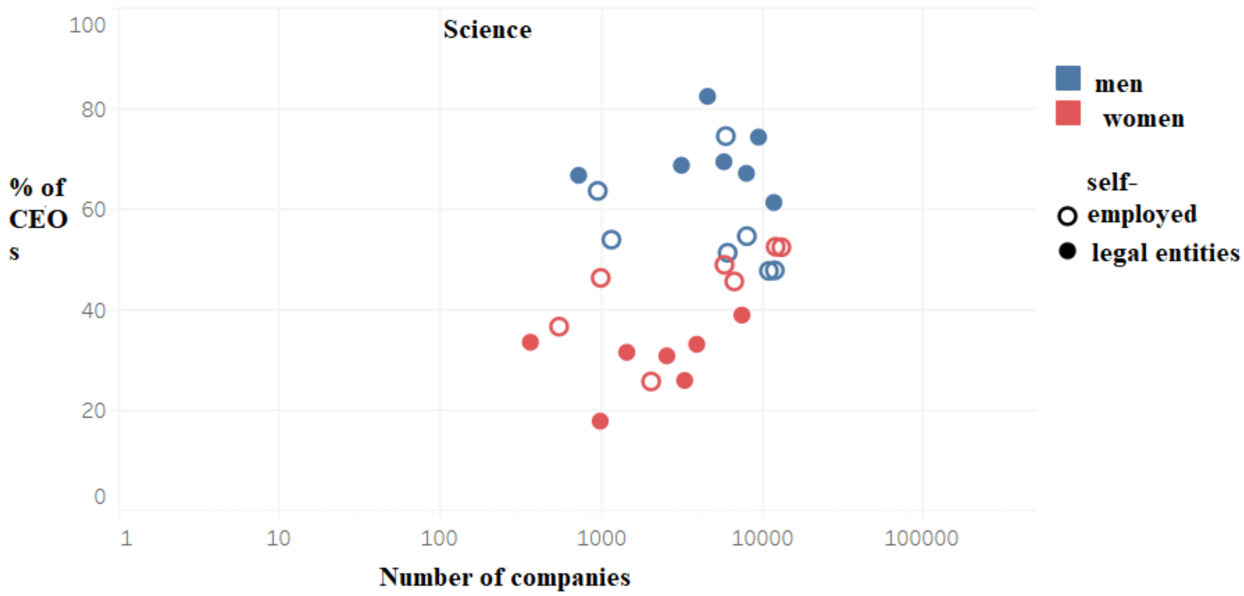
Global flood-related financial loss over 2000-2017 was USD 27 billion, of which even if the most conservative approach is considered i.e., 1% reduction in loss through using the flood risk assessment, mapping technology and early warning, then even significant savings of USD 270 million can be attained.

Preliminary targets for the transfer and diffusion of <u>Flood Risk Assessment and Mapping technology</u> are the design and implementation of physical measures and policy instruments for efficient flood-risk management and preventing flood loses on the basis of the widespread dissemination of information about technology benefits to the public, insurance companies and weather-related stakeholders.

Technology transfer and diffusion through the gender focus in water sector

As was mentioned in TNA report, Adaptation (TNA (2019), men and women are vulnerable to displays of climate change somewhat differently: in Ukraine, women tend to be more responsible for water availability in households. As for large-scale irrigation and involvement of men and women, studies in Ukraine are missing. For the contrary, it has been found that in Ethiopia, Ghana and Tanzania women benefit less from small-scale irrigation technologies (Theis et al 2017). Similar study on both small- and large-scale irrigation and its effect on women and men is needed in Ukraine. It is known that employment rate of women in Ukraine (52%) is slightly lower than that average in the EU (65%), however, only due to the differences of methodological approaches. One of the most significant reasons (being a reason for refrain from economic activities for 29% of women) for lower involvement in economic activities of women is domestic chores, which indicates unequal distribution of domestic chores between men and women. Nonetheless, 32% of employers are women. As of CEOs positions, there are 40% women-CEOs and 60% of men-CEOs, which can be explained by availability of men-only and women-only spheres, such as education (women-only) or processing industry, transport sector (men-only). Agriculture is the industry with a significant dominance of men on managerial and CEO positions: it 2017, out of more than 99 thousand self-employed persons in this field, only 18.4% are women. Therefore, agriculture is considered to be a mostly-men occupation. In water supply, the situation is not much better: out of nearly 10 thousand self-employed persons only 20% are women. Fig 2.1 indicates the gender distribution in water supply, agriculture and science, which is important for understanding of gender roles in water supply, large-scale irrigation and science behind studies and implementation of tools for drought and floods assessment and their mapping (SocialData 2017).





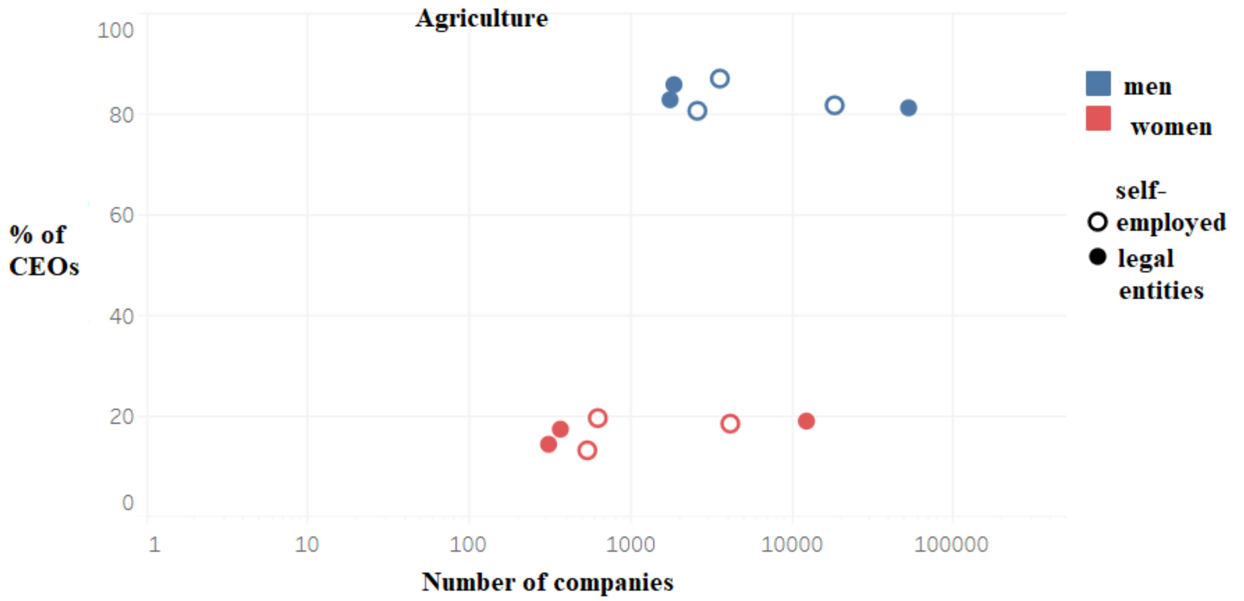


Figure 2.1 Gender of CEOs of companies in water supply, agriculture and science (SocialData 2017)

Southern and eastern regions of Ukraine are the ones that need irrigation the most (Fig.2.2). Luckily, in those regions the share of CEOs-women is one of the highest in the country. Therefore, women in these regions can potentially make decision on implementation of Climate-Smart Irrigation in Ukraine (even bearing in mind the fact that agriculture is a mostly-men occupation).

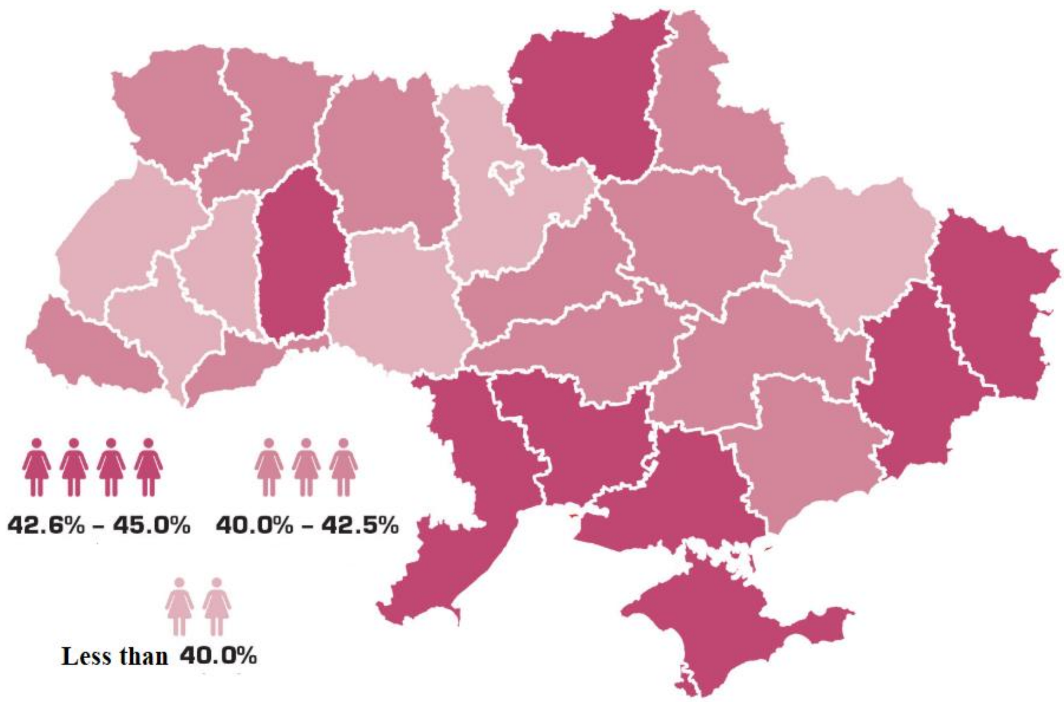


Figure 2.2 Share of women-CEOs and managers at legal entities region-wise (SocialData)

Both men and women require information on irrigation in general and on sparing water in all spheres of life (business, house chores etc). Women also require information on practical steps toward entrepreneurship in agriculture in general. Compared to water supply and agriculture, women have relatively good representative in science, which, together with proper financing, gives prospects to development and implementation of contemporary adaptation technologies in water sector.

2.2 Barrier analysis and possible enabling measures for climate-smart irrigation

2.2.1 The general description of technology

We consider the technology of “conventional” irrigation with smart elements i.e. not drip irrigation, because drip irrigation in Ukraine is mainly used for growing fruits, berries and vegetables, which is also confirmed by FAO. There is experience in growing corn with drip irrigation. FAO experts note that "Drip irrigation is most suitable for row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant. Generally, only the crops of high value are considered because of the high capital costs of installing a drip system" (FAO). As of 2019, in Ukraine, "smart" irrigation is used exclusively in the fruit and vegetable sector, as the cost of "smart" equipment is significant. For cereals, "smart" irrigation is not yet widespread, however, the worsening drought problem can appear in future, cereals will also be expected to be irrigated by using "smart" technologies. About 80% of Ukraine's agricultural land needs irrigation to achieve maximum crop’s yield. This problem will aggravate as drought in Ukraine is expected to be more severe and more frequent. More than that, this is expected to expand even to the Western and Northern regions of Ukraine (Adamenko 2020).

Briefly, the climate-smart irrigation technology comprises of several main “elements” – conventional irrigation technology (I) combined with elements that make it smart, i.e. use of sensors of meteorological stations (II).

(I). This technology is on early stage of its development in Ukraine. We do not have access to the companies who actually implemented the technology, therefore we undertake research on this topic and consider a hypothetical, however, appropriate to Ukraine context example. For being able to develop a hypothetical example, we conducted an interview with a representative of the company that sells the equipment for Climate-Smart Irrigation. Thus, in this hypothetical example, a system of conventional irrigation is the following:

The irrigation system includes a complex of interconnected structures and devices, which ensures the maintenance of an optimal water-salt regime in the upper soil layer for high crop's yields (State Building Codes 2000). The irrigation system includes a water source from where, through a pumping station with a pressure pipeline, water is fed into the receiving basin, it is further distributed by inlet channels (Kulibabin, Kichuk 2014).

(II) Climate-smart irrigation system is based on use on modern technologies, such as IoT (Internet of Things), different meters, drones, GSM, GLONASS, automated systems that are used to increase the productivity of agricultural output. In our case, a typical scheme of sensors for meteorological station consists of the following elements:

A base station (such as IMT 300). The approximate coverage area from the viewpoint of the high-precision local weather forecast service with an accuracy of 95% is about 5 km radius from the station. This station provides the data on:

- Air temperature,
- Air humidity,
- Water pressure deficit within the leaf,
- Solar radiation,
- Wind speed,
- Rain gauge (SmartWell LTD, 2020).

To control the humidity and soil temperature at the base of base station, **interface connection board and soil sensors** are ed.
For further economy on the equipment and in places where it is necessary on the basis of complexity of a landscape or necessity to irrigate different crops with different amount of water with the **offsets** such as ECOD3 and connection interface and soil sensor additionally for each such removal. The Frequency of installation for offsets is solely individual, but for calculation purposes we use 1 offset per 1 ha.

The schematic example of climate-smart irrigation technology is shown in Fig.2.3.

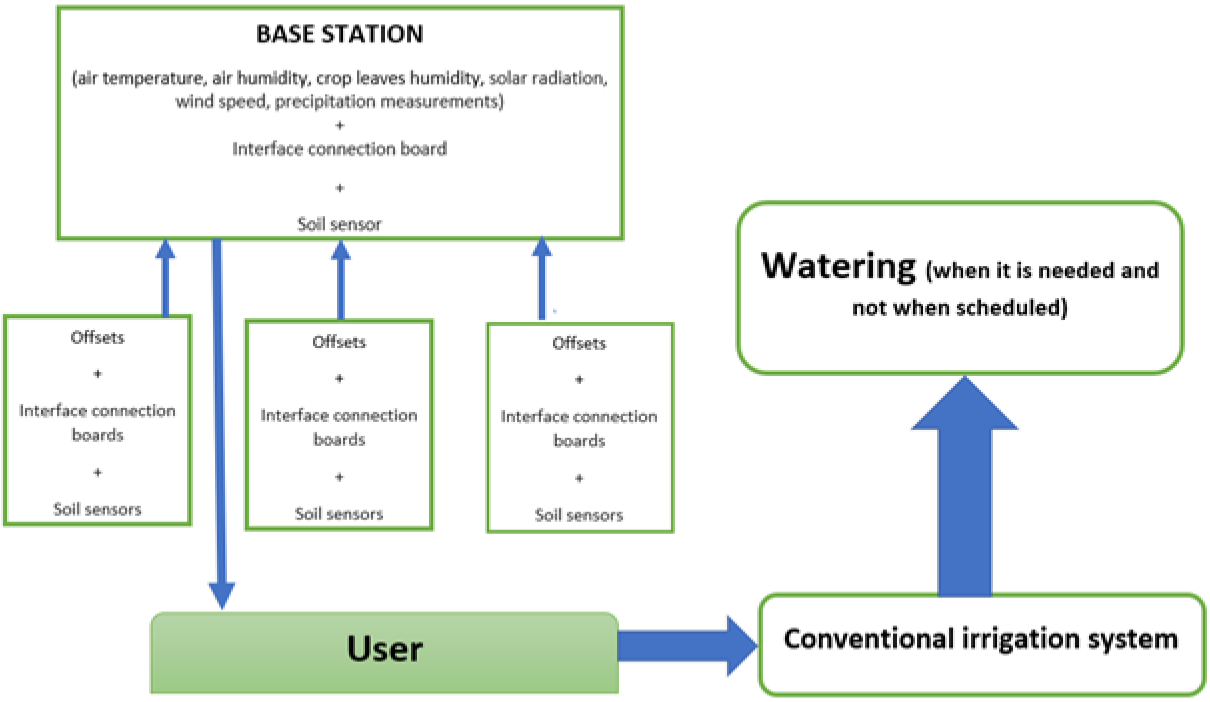


Figure 2.3 The brief depiction of climate-smart irrigation technology

This technology helps to water crops only when it is required (in contrast to watering on the basis of technological maps for crops or scheduled watering). Moreover, this technology is very important for the right dosage of nutrients (part of which, at the end, reach water bodies). In our hypothetical example, the implementation of climate-smart irrigation technology in Ukraine could be mainly driven by agri holdings and medium-sized farms (medium-sized farms are those with area of less than 3 thousand ha (in Ukraine, they process about 52% of arable land, agri holdings process 30% of arable land, whereas the remainder 18% of arable land are being processed by 15 million households), according to TNA Ukraine (2019). Further calculations indicate that Climate-Smart Irrigation technology is not cheap, therefore in the early stages of its implementation, it is not feasible to implement the technology by small market players such as households, but it can be afforded by medium-size agri producers. In Ukraine, the importance of meteorological information for agriculture is expected to grow as it can influence decision-making about the necessity to irrigate the crops etc. This, in turn, may promote more efficient use of water (Adamenko 2020).

In addition to conventional irrigation technology, the IMT300 weather station was used to provide a "smart" component, which records data for all climatic conditions with a solar-powered battery. The station has a built-in UMTS / CDMA modem for continuous reliable communication with the FieldClimate platform and can connect up to 600 sensors simultaneously. To enhance the system, offsets are used with connection interface boards and soil sensors capable of measuring soil's moisture, salinity and temperature. 200 sets of offsets and sensors were used for 1 ha per 5 ha. In our hypothetical example, we considered weather station IMT300, however, there are many other decent and reliable brands, for instance weather stations Davis, although they are slightly more expensive. It is mentioned that agricultural land area in Ukraine is 42 million ha, 80% of agricultural land is arable, 82% of arable land processors can potentially implement Climate-Smart Irrigation technology, we receive the maximal area of 27.5 million ha, that potentially can "host" Climate-Smart Irrigation. We are not able to estimate how many stations are required in the above-mentioned area, because farmers have plots of different shapes and with different relief. One should bear in mind that not all farmers processing 27.5 million ha of arable land would be willing to implement this technology due to various reasons. However, this technology is able to bring direct benefits to agri producers and farmers, as they would need to use less water and potentially to increase the harvest of planted crops (as less sprouts will die to under- or overwatering), as well as to IT specialists and importers of equipment. Should Ukraine be willing to implement domestic output of technology elements, it potentially can benefit machine building industry, especially small and medium enterprises, and create new jobs. Indirect benefits can be achieved by the entire society, as agri producers would use less water for irrigation, reducing the use of water for agriculture, and thus less nutrients would reach water bodies.

2.2.1.1. Economic analysis of climate-smart irrigation as climate change adaptation measure

In this subsection, conventional and no drip irrigation technology with elements of smart irrigation is considered and evaluated, because drip irrigation is not used for crops that are sown (wheat, barley, sunflower, etc.), while these crops form a significant part of the export potential and determine food security not only for Ukraine, but also for many countries globally. The technology of Climate-Smart Irrigation would be more and more required as water's demand would grow due to the worsening of environmental conditions, in particular the spread of drought and growing water deficiency. By 2019, climatic zones in Ukraine have migrated toward north. 1°C temperature increase to move the boundary of agroclimatic zones 100 km to the north. It is apparent that in Ukraine the average temperature's increase is almost 2°C during the last 28 years, the agroclimatic zones have already moved 200 km to the North (Landlord 2019b). It means the area of Steppe is increasing and will continue to increase. The speed of this increase depends on mitigation factors as well as on climate per sei. At a first glance, Steppe is a primary climatic zone for the technology implementation. Regions that require Climate-Smart Irrigation are mostly located in Kherson, Odesa and Mykolaiv regions. Pilot area might be limited to Kherson region, as this region is the most arid and has Kakhovsky Irrigation Channel – a major irrigation channel in Southern Ukraine. The timeframe for pilot project can be 6 years, as this period is enough for technology payoff. The upscaling phase may take another four years.

Taking into account climatic zone's migration, in the closest future, Steppe will include Odesa, Kirovograd, Cherkasy, Poltava. Kharkiv, Luhansk, Donetsk, Dnipro, Mykolaiv, Kherson, Zaporizhzhya regions and the Crimean Peninsula. However, the fact is clarified that Polissya is getting warmer faster than Steppe, Polissya also requires Climate-Smart Irrigation. The areas in Polissya that would require this technology might include Sumy, Kyiv, Chernihiv, Zhytomyr, Rivne and Lviv regions.

As of April 2019, there were about 2.5 thousand weather stations in Ukraine, being installed within the last 10-12 years. Unfortunately, farmers were not able to benefit fully from the use of weather stations, and majority of them became obsolete and unfunctional, so now they require modernization or repair that might costs as much as the brand-new station. Weather stations were not used combined with the available irrigation infrastructure. However, nowadays agri holdings create special units for the data analysis and creation of weather station networks. (Aggeek 2019). The market is far from being saturated, so Climate-Smart Irrigation technology has a significant potential of implementation.

The following assumptions were used in the calculation:

- The size of farm plots – 1 thousand ha. This particular size is sufficient to implement five-course rotation, because 82% of arable land operators manage plots of more than 3 thousand ha;
- Equipment's installation cost is 90% of the equipment cost (Sidorenko, Lilevman 2018);
- Water consumption rates for irrigation are shown in Table V W-01 (in Annex);

- When using climate-smart irrigation, 50% less water is used (Chandler 2019). Of all water consumed for irrigation, an average of 60% is simply lost (Daga 2018). Global experience shows that during arid years, up to 60% of water is saved, up to 80% of water during years with excessive humidity using only climate-smart irrigation technology;
- We assume that crop's yields will be the same for traditional and climate-smart irrigation because the "end product" we are interested in is saved water. In fact, with climate-smart irrigation, crop's yields are usually higher than using conventional irrigation, as fewer sprouts die to overwatering or underwatering;
- Exchange rate: 1 USD = 26 UAH;
- The cost of water supply from the channel - UAH 1.25/m^3;
- Electricity costs for water supply from the canal – UAH 0.75/m^3;
- We assume that projects of conventional and climate-smart irrigation will run 10 years.

For being able to conduct a cost-benefit analysis, we used the data on irrigation norms for conventional agriculture (Table V W-01 in Annex). Later, we reviewed the composition of both conventional and climate-smart irrigation systems and investments required (Table V W-02 in Annex). Fertilizer distributors are also included in the structure of the irrigation system.

Our calculations indicate that the cost of conventional irrigation equipment is USD 2833/ha and the cost of climate-smart smart irrigation USD 4251/ha. The capital expenditures we obtained in our hypothetical example are fully commensurate with the costs of irrigation facilities provided for the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, approved by the CMU Order of the 14th August, 2019 No. 688-p. According to the latter, investments in the construction of the new irrigation system are on average USD 2500 / ha.
Later, we calculated the return on a 5-pole system, that is, a system in which 5 crops are grown simultaneously in fields, 200 ha each (Tables V W-01-08 in Annex).

The production costs of the yield were calculated. The production costs consist of the following elements:
- the cost of rent for arable land UAH 2065/ha (Zhurakivska 2019);
- insurance payments (5% of direct operating costs) (Sidorenko, Lilevman 2018);
- storage and sales costs (5% of direct operating costs) (Sidorenko, Lilevman 2018);
- other costs (such as transport, 10% of direct operating costs) (Sidorenko, Lilevman 2018);
- other production costs (5% of direct operating costs) (Sidorenko, Lilevman 2018).

Next, we calculate the operating costs of yield of the same crops with climate-smart irrigation.

Financial indicators (NPV, IRR. Tables 2.1. - 2.3) of both hypothetical projects were assessed. We calculate NPV at different discount rates - 22%, 19% and 11%. The NBU discount rate as of April 2020 is 10%, but the actual rates of lending by commercial banks are 19-22% (since the NBU discount rate began to decrease only at the end of 2019, and commercial banks do not lower their rates).

Table 2.1. Simple payback time (SPT)

	Conventional irrigation	**Climate-smart irrigation**
SPT, years	3.8	5.7

Table 2.2. Net Present Value (NPV)

	Discount rate	**Conventional irrigation**	**Climate-smart irrigation**
NPV	22%	1 524 684	-35 285 195

NPV	19% (NBU 2020)	9 753 274	-27 050 006
NPV	11%	40 436 960	3 658 292

As can be seen from the table, NPV will be positive for a conventional irrigation project for 10 years, and it is negative for a climate-smart irrigation. Our calculations have shown that for the latter NPV will be positive, if the interest rate drops from 22% to 11%.

If we apply time series for the cash flow, we receive positive NPV for both types of irrigation after 5 years of full implementation of the projects even at 19% discount rate.

Two important conclusions are drawn from this calculation: 1) for climate-smart irrigation technology, capital in Ukraine is too expensive; 2) if the government is interested in saving water, reducing the overflow of nutrients into water basins and increasing the yield of strategic agricultural products, the development of state programs for the reduction of capital is necessary precisely for the promotion of climate-smart irrigation projects, which can be made possible in the first place in cooperation with international financial institutions. The government of Ukraine cannot provide direct financial subsidies as Ukraine is an important exporter of agricultural goods, thus direct financial subsidies would violate WTO provisions. Therefore, it is reasonable and acceptable to establish financial aid in at least two following forms:

- The reimbursement of interest rate for loans obtained from commercial banks to purchase equipment for Climate-Smart Irrigation;
- To assign Codes to the equipment for Climate-Smart Irrigation within Ukrainian Industry Classification System and to establish tax exemptions for imported equipment.

It is worth remembering that, apart from the high sensitivity to the discount rate, the NPV financial calculation for these projects is purely hypothetical: it is assumed that the financial returns are the same every year, but in the real world, this is not true due to fluctuations in crop yields, volatility food market prices and more. Besides, projects can last more than 10 years. The fact is mentioned that a 10-year project is a long-term, if we apply time series for the cash follow, the IRR would become even higher.

Table 2.3. Internal Rate of Return (IRR)

Conventional irrigation	Climate-smart irrigation
Without consideration of time series for cash flow	
23%	12%
With consideration of time series for cash flow	
33%	21%

Source: own calculations

From a financial point of view, the conventional irrigation project is more attractive as the IRR is higher than the discount rate (23% higher than 22% and 19%). However, if ways to reduce the cost of capital to 11% are found, the project "climate-smart irrigation" will also be feasible. This confirms the importance of the previous thesis, in particular regarding the need for cheaper capital.

2.2.2. Identification of barriers for technology

The barriers were identified with the help of the Second Edition of Guidebook on Overcoming Barriers to the Transfer and Diffusion of Climate Technologies developed by UNEP DTU

Partnership (Nygaard, Hansen 2015). Climate-smart irrigation technology was considered as a Market Good, in particular a Capital Good technology, as it is typically purchased by private business, requires significant investment, that currently can be afforded mainly by large agri producers. This technology is used to produce other goods (crops in our case). All irrigation practices in the area above 20 ha in Ukraine undergo Environmental Impact Assessment (in accordance with the Law On Environmental Impact Assessment). Irrigation equipment has substantial payback period (more than five years). In order to identify the barriers related to climate-smart irrigation technology, national consultants have conducted a desk research and a number of consultations with experts in the field of irrigation.

2.2.2.1. Economic and financial barriers

- **The high cost of technology**. This technology requires large investment. As the result, only agri holdings and large agri producers can often afford climate-smart irrigation technologies.
- **The high cost of capital.** The weighted average cost of capital (WACC) in Ukraine is 15%, on the basis of 2019 calculations (Trypolska 2019). According to market analysts, actual WACC in Ukraine can be as high as 19%. These are rather high values, especially compared with the European countries (LB.UA 2017). In the OECD countries and China, it does not exceed 10% (IRENA 2018). The difference in WACC values can be explained with the fact that WACC value is highly sensitive to the discount rate. The discount rate, in turn, depends on particular conditions of loan provision that a bank may offer. WACC value also depends on the ratio of borrowed/own capital (the higher share of own capital, the lower is WACC value). Therefore, different companies even in a country might have different WACC rates.
- **Difficulties with access to capital.** Irrigation projects require so-called long-term loan, i.e. loan for more than 5 years. In contrast, banks are inclined to provide loan only for seed and plant-protection agents (Babchuk 2016). As the result, mostly only Agriholdings and medium-sized farmers can afford climate-smart irrigation technologies.

2.2.2.2. Non-financial barriers

- **The inconsistency of property rights**. According to the Head of Institute for Water Problems and Amelioration, UNAS Dr Romaschenko, inter-economic irrigation network (water intake structures, pumping stations) remains the property of the state. This network is managed and operated by the State Water Resources Agency. During Soviet time, the domestic irrigation network (pipes that lead from the pumping station directly to the irrigation sprinkler plants) was in the balance of collective farms (kolgosps). In fact, it belonged to the state and former Ministry of Agriculture was in charge of this equipment. After the adoption of the Law of Ukraine "On Amelioration of Lands" (2000), in 2003, by a decree of the Cabinet of Ministers, these networks were transferred to the property of local (village) councils, that had neither the fund nor the specialist to attend them. It led to physical destruction of the networks (digging the pipelines and selling the sprinkling machines to scrap) (Babchuk 2016). As for climate-smart irrigation technology, a conflict of interest might appear, as inter-economic irrigation network elements are managed and operated by the State Water Resources Agency, i.e. it does not belong to companies implementing this new technology.
- **Water for irrigation tariff is insufficient for capital assets renovation**. The cost of electricity comprises of 60-80% of water for irrigation tariff. Funds obtained from selling water for irrigation are not enough for repairs or modernization of irrigation networks (Babchuk 2016). Usually, the tariff for goods and services includes the element “investment program”, but money is not being allocated to fulfill the investment program. In other words, companies that operate infrastructure for irrigation do not have money to renovate the equipment. Climate-Smart Irrigation consists not only of “smart” elements, but also of equipment for physical irrigation.

- **Limited availability of local suppliers of equipment and services**. There are Ukrainian companies producing equipment for conventional and drip irrigation. They include companies “Irrigator Ukraine” (Odesa, production of pipelines for drip irrigation), “Santechplast” (Kharkiv, output of film pipelines), “Fregat” (Pervomaysk, Mykolayiv region, production of irrigation sprinkler plants and irrigation valves) (Babchuk 2016). However, climate-smart irrigation technology is a high technology, especially the elements that define its “smartness”, are not being produced in Ukraine.
- **Lack of awareness and limited knowledge of the benefits of technology**, as technology is new not only for Ukraine but globally. It leads to limited expertise in its arrangement and daily operation. It also requires teaching of personnel for its daily operation and maintenance.
- **Obsolete and physically missing infrastructure for irrigation.** During Soviet time, there were more than 30 thousand irrigation sprinkler plants. In 2013, less than 6 thousand of those remained. More than 360 thousand ha of domestic irrigation networks were stolen and destroyed. After land parceling, many plots of land were transferred to new owners as lands that require irrigation, but they were managed as rain-fed land due to lack of money to maintain irrigation infrastructure. As the result, domestic irrigation network is capable of watering about 2 million ha, but in fact only 0.5 million ha are irrigated. Because of obsolete equipment, during the transportation of water, annually 300-500 million m3 of water is simply lost (Babchuk 2016).
- **Lack of detailed assessment of water available for irrigation.** Due to hydrological drought, rivers are shallowing in Ukraine. There are many irrigation systems that use water of Dnipro river, which shallows and steadily turns into the cascade of bogs (DepoDnipro 2016). Understanding of limitations (of scarcity) of available water should promote more reasonable and justified use of available fresh water, and to promote use of grey water.
- **Unauthorized and untreated extraction of water for irrigation from artesian field**. This leads to short-term benefits for agri producers, but exhaust the deposits of fresh artesian water, distorts the competition (as majority of agri producers pay for water) and negatively interferes in the local water circuit. Since water extraction is unauthorized, there is no official data on the amount of water extracted.
- **No legislation regulating climate-smart irrigation technology**. This technology is new, so it requires the introduction and development of respective legislation.

The fact is mentioned, that construction of new irrigation facilities ceased during the last two decades in Ukraine (Pedak 2013), the reasonable use of remaining infrastructure combined with modern smart technologies can be a reasonable adaptive measure in view of climate change and water deficiency in Ukraine, and bring benefits to agri producers.

Experts were suggested to assess the significance of each barrier by attributing scores from 1 to 5 to each barrier, where 1 is insignificant barrier and 5 – very significant barrier. Later, the obtained scores were summed up for each barrier, allowing national consultants to distinguish the importance of each barrier (Table 2.4).

Table 2.4. Importance of barriers for Climate-Smart Irrigation Technology

Significance	Identified barriers	Description of barrier
Very important	High cost of capital	Economic and Financial
	Difficulties with access to capital	Economic and Financial
	No legislation regulating climate-smart irrigation technology	Legislative

	Obsolete and physically missing infrastructure for irrigation	Technical
Important	High cost of technology	Economic
	Lack of detailed assessment of water available for irrigation	Informational
	Inconsistency of property rights	Legislative and Regulatory
	The limited availability of local suppliers of equipment and services	Technical
	Unauthorized and untreated extraction of water for irrigation from artesian fields	Regulatory
Less important	Lack of awareness and limited knowledge of the benefits of technology	Informational
	Water tariff for irrigation is insufficient for the renewal of capital assets	Economic

The logical analysis of problems for economic, financial and non-financial barriers to the spread of climate-smart irrigation technology is shown in Fig. IIW – 01 (in Annex).

2.2.3 Identified measures

2.2.3.1 Economic and financial measures

Economic and financial barriers are quite significant for climate-smart irrigation technology. Calculations in section 2.2.1.1. indicate that climate-smart irrigation technology is economically feasible only when the discount rate does not exceed 11%. It is ensured that, long-term credit funding (loans) from international financial donors is required (to overcome the barrier of high cost of capital). Loan could be provided from international organizations through Ukrainian commercial banks that can choose the qualifying projects within a special funding program aiming at different technologies of improved irrigation (to overcome the barrier of difficult access to capital). Moreover, fiscal preferences could be of help, such as import's tax exemption (when importing equipment such as sensors). The complex of these measures would help to overcome the problem of high cost of technology. To summarize, the following measures are required:

- *Special funding program*. The purpose of the program is to explain the importance of Climate-Smart Irrigation, and to show "green light" to both companies that can potentially implement the technology and banking system. Fund can be allocated through state-owned banks. Since the Government cannot provide direct financial subsidies, fund could be provided either by International Financial Organizations, or through the program already existing in Ukraine (such as Global Environmental Facility. However, Ukraine has already exhausted 76% of the funds allocated to Ukraine). Hopefully, in future, Ukraine will be able to join Green Climate Fund, that potentially can become the source of finance;
- *Long-term soft loan*. They can be provided by state-owned and private banks, provided the difference between the "market" and low interest rate will be covered either by the Government, or by regional authorities, or by international financial organizations;
- *Import tax exemption* to ensure the import of necessary equipment.

2.2.3.2 Non-financial measures

Ways to overcome the remainder (non-financial) barriers are provided in the table 3.5 below.

Table. 2.5. Non-financial barriers and measures to overcome them to implement climate-smart irrigation technology

Barrier	Measure
Inconsistency of property rights	- The creation of water users' associations (WUAs) within the basin. It is the primary measure for managing the inter-grid networks and then transferring the inter-grid networks to the balance of associations. This will allow such organizations to identify the areas requiring irrigation and obtain credits. - The development of mechanisms for state support for the acquisition of irrigation machinery and elements of the climate-smart irrigation system by farmers. During previous years, the management of water bodies by the basin principle was introduced. - The transmission of local level irrigation networks as part of the decentralization process to the local governments, and credit or investment resources can be mobilized there by local government efforts.
Cheap water for irrigation	- Slow increase in water tariff by WUAs (until the tariff reaches the size of prime cost), so that tariff for irrigation would cover not only the cost of electricity, but also the innovation and development expenditures. At the first glance, this measure will increase the expenditure of water users, but this measure is necessary for the renewal of main water pipes etc. This way, increased tariff would benefit many beneficiaries and not only agri holdings.
Limited availability of local suppliers of equipment and services	- The development of complex national target economic program stimulating machinery output (production of equipment for irrigation, for energy sector etc). - The cooperation of machinery producers with IT companies (to guarantee consistent development of hardware and software for the technology). - The establishment of domestic production facilities, i.e. partial conversion of existing factories and plants to produce equipment that could be of use for conventional and Climate-Smart Irrigation.
Low awareness on the benefits of technology	- The study of international experience. - Awareness raising campaigns that could be conducted by equipment sellers. - The inclusion of information on climate-smart irrigation technology into the curricula of universities. - Training programs for representatives of agri companies.
Obsolete and physically missing infrastructure for irrigation	- The renovation of infrastructure for irrigation, in particular- the modernization of networks in several regions; the replacement of equipment at main pumping stations; equipping of inter-farm systems with modern means of water accounting; introduction of reserve capacities, which should be determined individually by the

	results of technical inventory and energy audit; the assessment of demand and need to expand the irrigation area in particular areas. - The modernization of irrigation networks in one region be means of increasing water- and energy efficiency of used equipment, repair or construction of water pipes, renovation of sprinklers.
Lack of detailed assessment of water available for irrigation	- The analysis and modelling of available rivers, as well as forecasts of how drought will affect the availability of water in rivers in Ukraine.
Unauthorized and untreated extraction of water for irrigation from artesian fields	- Thorough the control of water withdrawal by controlling bodies.
No legislation regulating climate-smart irrigation technology	- The development of respective legislation by means of extending the existing Strategy of irrigation and dewatering in Ukraine by 2030.

To summarize, measures identified are presented in Fig. II W-02 and Market mapping is presented in Figure II W-03.

2.3. Barrier analysis and possible enabling measures -Drought risk assessment and mapping technology

2.3.1. The general description of technology

The description of Drought risk assessment and mapping is a key element of drought management, as it helps identify most of areas at the risk of drought, allowing communities to plan, as well as prepare for and mitigate possible impacts. Drought's risk is calculated as the probability of negative impact caused by interactions between hazard (probability of future drought events occurring based on past, current and projected drought conditions), exposure (scale of assets and population in the area) and vulnerability (the probability of assets and population being affected by drought in the area).

Drought is a complex natural hazard that impacts ecosystems and society in many ways. Many of these impacts are associated with hydrological drought (drought in rivers, lakes, and groundwater). Research in the early 1980s uncovered more than 150 published definitions of drought. Definitions reflect differences in regions, requirement, and disciplinary approaches**.** Wilhite and Glantz (Wilhite at.al.,1985) categorized the definitions in terms of four basic approaches to measuring drought: meteorological, hydrological, agricultural, and socioeconomic. The first three approaches deal with ways to measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall, as it ripples through socioeconomic systems.

Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of

meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.
All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency (Fig.2.4).

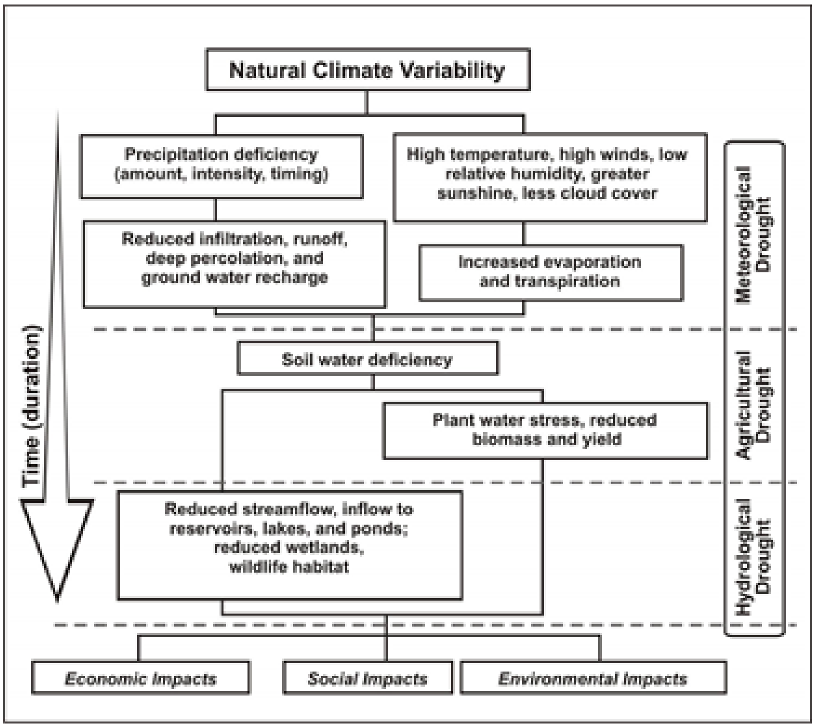


Figure 2.4. Sequence of drought occurrence and impacts for commonly accepted drought types (Source: National Droughts Mitigation Center, 2020.)

Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so on. The demand of plant water depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per hectare and a reduction of final yield. However, if topsoil moisture is sufficient for early growth requirements, deficiencies in subsoil moisture at this early stage may not affect final yield, if subsoil moisture is replenished as the growing season progresses or if rainfall meets the irrigation requirement of plant.

Hydrological drought is associated with the effect of periods for precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). The frequency and severity of hydrological drought is often defined in a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological drought is usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and groundwater and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately discernible to agriculturalists, but the impact of this deficiency on reservoir levels may not affect hydroelectric power production or recreational uses for many months. Moreover, water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water user's increase significantly.

Drought assessment and mapping technology consist of 6 stages (Fig.2.5.):

1. Collection of observational data for drought assessment;
2. Data preprocessing;
3. Formulation of methodology for drought assessment;
4. Assessment of drought;
5. Mapping;
6. Transfer of technology products to Risk Management Authority and other stakeholders

In the first stage of the technology, all kinds of the information required for drought assessment must be collected. Data for drought risks assessments include that derived from remote sensing (Kussul at al.,2014), as well as field measurements, in case of possibility. For the calculation of typical drought, indexes SPI or SPEI is needed data of field measurement: daily and monthly values of temperature and precipitation, soil moisture. Remote drought monitoring is carried out on the basis of the use of the Normalized Vegetation Index (NDVI), or the normalized NWI water index, calculated by satellite data TERRA / MODIS and other satellites.
For the calculation of drought indices, availability of long time series of undisturbed, good-quality of observational data is essential. Observational data sources used in drought studies are either station data (e.g., meteorological stations, discharge gauging stations, groundwater wells) or gridded data (e.g., reanalysis data, satellite data). In hydrological drought studies, most commonly used data are streamflow measurements (Van Loon, 2015).

In the second stage of the technology all data, including basic quality control, generation of meteorological, hydrological or satellite parameters requireded for drought indexes (DI) calculation, verification and validation must be processed.

In the third stage, there must be the formulation of the technology for drought assessment and should be selected of type of DI (on the basis of meteorological, hydrological, or satellite observational data).

A group of drought indices are standardized drought indices. They have in common that they represent anomalies from a normal situation in a standardized way. The advantage is that regional comparison of drought values is possible. A drawback of standardized indices is that the severity of a drought event is expressed only in relative terms, while in water resources management, absolute values of the lacking amount of water are needed with regard to 'normal' conditions (i.e., deficit volume). The set of standardized drought indices (including those focusing on hydrological drought) originate from the Standardized Precipitation Index (SPI).

SPI is the most-used standardized meteorological drought index. It is based on long-term precipitation records that are fitted to a probability distribution. This distribution is then transformed to a normal distribution, ensuring zero mean and unit standard deviation. Because precipitation has a high spatial and temporal variability, meteorological drought indices often use monthly values. SPI can be computed over several time scales (e.g., 1, 3, 6, 12 months, or more) and thus indirectly considers effects of accumulating precipitation deficits.

Experts participating in a WMO drought workshop in 2009 recommended that the SPI be used by all National Meteorological and Hydrological Services (NMHSs) around the world to characterize meteorological drought. Advantages of SPI are that its calculation results in normalized values and that it can be computed for different time scales. Disadvantages of SPI are that only precipitation is considered, while other meteorological drivers might be important too. Additionally, the length of a precipitation record and the fitted probability distribution have significant impact on the SPI values. Finding the most suitable distribution can be a challenge, especially in dry climates, which limits the use of SPI on a global scale.

As precipitation is not only meteorological variable influencing drought conditions, some meteorological indices also include (a proxy for) evapotranspiration. As an alternative for SPI, Vicente-Serrano etc. developed the Standardized Precipitation and Evapotranspiration Index (SPEI). SPEI considers the cumulated anomalies of the climatic water balance (precipitation minus potential evapotranspiration) and, like SPI, fits a probability distribution and transforms it into a normal distribution.

Standardized indices for the characterization of hydrological drought use different hydrological variables (from observed or simulated data) as input. Most common is a focus on streamflow, because streamflow is most measured, most easily simulated, and of most interest to water resources management. Other variables used in hydrological drought indices include groundwater levels and lake levels. The Standardized Runoff Index (SRI) uses the simulated runoff and the Standardized Streamflow Index (SSI) focuses on (observed or simulated) streamflow. Both have a calculation procedure similar to SPI, fitting a distribution to the data and transforming it to a normal distribution. On the basis of a similar principle, but using a nonparametric transformation instead of distribution fitting, is the Standardized Groundwater level Index (SGI), recently developed by Bloomfield and Marchant. The limitations of SPI also apply to SRI/SSI and SGI, i.e., the length of the data record and the fitted distribution strongly influence SRI/SSI and SGI (Van Loon, 2015).

Since standardized indices with similar calculation procedures are available for all variables of the terrestrial hydrological cycle (i.e., SPI, SPEI, SMRI, SMA, SRI/SSI, SGI), they can be a useful tool in drought propagation studies, in which drought is compared in different compartments of the hydrological cycle. The standardized meteorological indices of drought (on the basis of precipitation only, e.g., SPI), calculated over long time scales are sometimes used as an approximation of hydrological drought. In other studies, this is not recommended as indices on the basis of precipitation alone cannot capture all relevant propagation processes.

The implementation of hydro-meteorological or hydrological indicators, such as the Normalized Difference Vegetation Index (NDVI) (uses light reflection from vegetation to detect changes in health including drought related stress), or Standardized Precipitation-Evapotranspiration Index (SPEI) (compares water availability to evapotranspiration rates) are common indicators in order to be used to assess drought risks that work by implementing the remote sensing to determine potential drought hazards. This data can then be coupled with data on population and assets in the area, as well as the community's vulnerability to damage by drought, to assess the drought risk.

For this technology, SPI index can be recommended, as recommended by WMO for drought monitoring over the world. SPI uses historical precipitation records for any location to develop a probability of precipitation that can be computed at any number of timescales, from 1 month to 48 months or longer. As with other climatic indicators, the time series of data used to calculate SPI does not need to be of a specific length. SPI can be calculated on minimum 20 years' worth of data, but ideally the time series should have a minimum of 30 years of data, even when missing data are accounted for.

When satellite data are used for identifying and monitoring drought, index NDVI is recommended. Radiance values measured in both the visible and near-infrared channels are used to calculate NDVI. It measures greenness and vigor of vegetation over a seven-day period as a way of reducing cloud contamination and can identify drought-related stress to vegetation. Input parameters: NOAA satellite data.

In the fourth stage, drought must be assessed, including daily data transformation into DI, DI database creation, DI ranging (5 classes of DI) /classification (United,2020). Spatial data from the paper maps, remote sensors and records are required to be transformed into a digital format and create a spatial database of DI. Geographic references (longitude or latitude/columns and rows – spatial data) identify the spatial location of information collection.

In the fifth stage, there must be the mapping of drought. This final stage of technology seeks next technical procedure with DI spatial database like spatial DI interpolation, visualizing resulting DI maps, publicly available DI maps publication. The creation of risk maps requires Geographical Information Systems (GIS) software. To carry out it, the spatial data analysis can be used for next GIS software: MapInfo, ERDAS, Intergraph, IDRISI, GRAM, ArcInfo, GRASS, AutoCAD maps etc.

Drought risk's modelling must also consider climate change trends in the area in order to calculate the effect they may have on drought's impacts. All spatial data's models use discrete spatial data objects such as points, lines, areas, volumes and surfaces. Attributes are both spatial and non-spatial and the digital description of objects characterize them and their attributes comprise of spatial data sets. Vector and raster models are commonly used in data organization

When an attribute is measured at sample point, it is spatially continuous and a single-valued surface. Interpolation methods are effective for converting points to an area representation. The interpolation process involves estimating the value of the modelled variable at a succession of point location, usually on a square lattice and is called gridding. The gridded values are treated as the pixels of a raster image. These grid values are used in contour lining or surface modeling or as labelled line objects or polygon objects whose boundaries are the contours. The process of converting point data to data structure that represents a continuous surface is called contouring or surface modelling. Surface modelling is achieved through triangulation, distance weighing and Kriging (Nagarajan,2010).

For the mapping of drought, the most widely used ArcGIS in Ukraine, developed by the Institute for Environmental Systems Research (ESRI), can be recommended (About ArcGIS,2020). ArcGIS offers a unique set of capabilities for applying location-based analytics to drought mapping, contextual tools to visualize and analyze ground based and satellite data. It includes imagery tools and workflows for visualization and analysis, and access to the world's largest imagery collection.

Drought's risk assessment is often accompanied by drought forecasting and monitoring measures. Selected drought's risk indicators are monitored and projected to enable drought early warning.

In the sixth stage, there is a transfer of results and products of technology (drought risk maps, drought forecast, relevant drought information) to the Risk Management Authorities and other stakeholders. Risk Management Authorities in Ukraine are State Emergency Service (Risk Management Department), River Basin Authorities, Ministry of Agrarian Policy and Food, State

Water Agency. Among other stakeholders, there can be insurance companies, state and private agrarian farms, municipalities in drought regions, NGOs and media.

Environmental Benefits - Protects vulnerable ecosystems against effects of drought in high-risk areas where drought impacts are exacerbated by human activity. - Contributes to reduced land degradation and desertification.

Socio-economic Benefits - Improves drought mitigation and management in high-risk areas and in consideration of factors that may exacerbate the impacts. - Creates visual products that may improve the understanding of climate-related risks and threats amongst key stakeholders. - Informs better identification of response measures, e.g. water-retaining agricultural practices, water storage, fixing leaks in municipal water supplies, promotion of water-saving techniques in households.

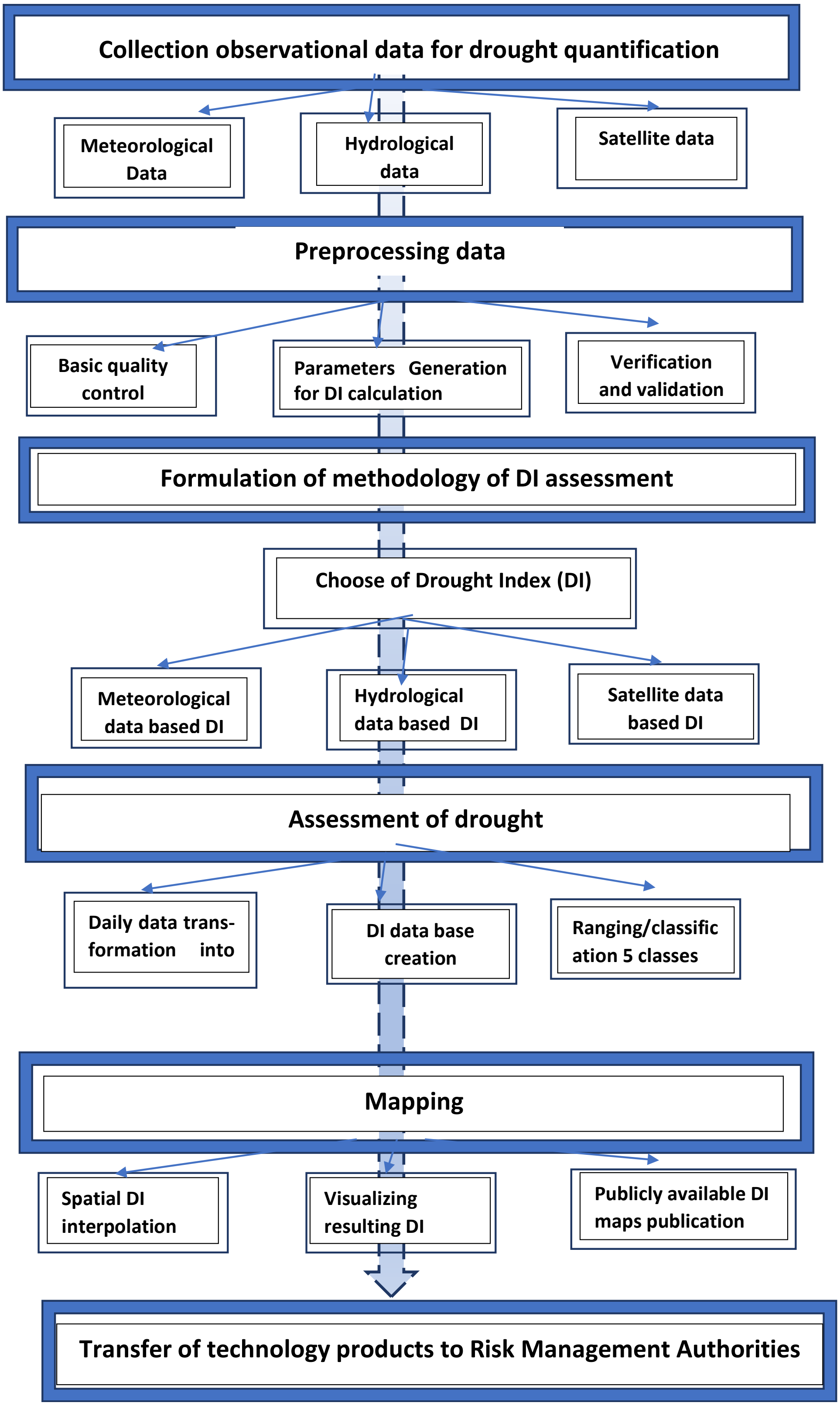


Figure 2.5. The technological structure of drought assessment and mapping technology

2.3.2. The identification of barriers for technology

Drought's hazard assessment and mapping technology belong to subcategory "other non-market goods" in category "non-market goods" according to its relationship to the market (Nygaard,2015). Usually, the category of "other nonmarket goods" presents non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs. These technologies are not transferred as part of a market but within a public non-commercial domain.

For non-market goods technologies, such as flood risk assessment and mapping, drought risk assessment and mapping, barriers may be identified with the support of a cost benefit analysis for the social and environmental costs of technologies.
According to Barrier guidebook, non-market technologies are not traded in the marketplace and most often financed by public institutions or by donors rather than by users, their competitiveness should, in general, be understood in a broader social and environmental context.

For the identification of economic and financial barriers, the tool of logical problem analysis (LPA) was used. This tool helped to identify major problems in the transfer of technology, a hierarchy of barriers and relevant reasons, in order to build the tree of logical problem, which indicated the main relationship between causes and effects, to find logical structure and relationship with external factors.

2.3.2.1. Economic and financial barriers

The implementation of technology requires significant economic and financial barriers to be overcome, as it requires significant and stable financing over a long period of time in a weakened economy due to the war in eastern Ukraine, which has led to the loss of a large number of budget-filling industries in the Donbas region.

Moreover, Russia's military expansion into Crimea led not only to the loss of administrative integrity and disruption of economic stability due to the suspension of budget revenues from the region, but also to indirect and unplanned budget expenditures related to the restructuring of industrial and territorial complexes, accommodation of war refugees, etc. For this reason, in recent years, public spending on environmental issues, research, education has declined significantly.

At the same time, the functioning of this technology is possible only if there is high quality of meteorological and hydrological monitoring data according WMO standards provided by the National Meteorological and Hydrological Service (NMHS) of the State Emergency Service of Ukraine (SESU). Unfortunately, due to the lack of state funding for the monitoring service (an average of 53% of the needs) of the 22,000 core technical facilities of the observation network, more than 90% work with exhausted operational resource, 50% require immediate replacement. For the timely detection and identification of hazardous and natural hydrometeorological phenomena, as well as timely warning of the likelihood of their occurrence, it is necessary to develop meteorological radar observations, the system of which currently covers only 15% of the territory of Ukraine. Meteorological Radar Network has only four meteorological radars that are morally obsolete and worn out (Meteorological and meteorological cell of UAMC Boryspil, IRL-5 AMC Zaporozhye, IRL-2 AMC Khmelnitsky, Chernivtsi).

In 2007, at the request of the Ministry of Emergencies and for the Protection of the Population from the Consequences of the Chornobyl Catastrophe, experts from International Bank for Reconstruction and Development (IBRD) evaluated the cost-effectiveness of the development of the Hydrometeorological Service of Ukraine and prepared an appropriate report ("Economic efficiency assessment of the Program of technical and technological development of hydrometeorological service of Ukraine) (Evaluation, 2007). According to this estimate, the technical resource for the use of 7 meteorological locators, information, which are urgently required for the study of natural hydrometeorological phenomena (floods, droughts), exceeded by 1.3-8 times, 9 locators by 1.3-9 times.

Water level recorders, hydrometeorological units have 100% exhausted their operational life! It is revealed that a significant drawback of the Hydrometeorological Monitoring Service in Ukraine is the practically lack of automated technical complexes for measuring meteorological and hydrological parameters necessary for the assessment and mapping of drought and floods. It is established that the level of use for the remote means of receiving information is extremely low, there are practically no modern Doppler radars, insufficient level of use for the information of meteorological satellites. These factors cause the lag of Ukraine's hydrometeorological service from the services of the leading countries in the world, and deteriorate the quality of the observation data. In terms of the implementation of drought and flood risk assessment technologies in Ukraine, this is a very serious barrier that will not allow a high-quality assessment of these phenomena and their mapping.

An evaluation of the effectiveness of hydrometeorological services was conducted by the experts of the European Bank for Reconstruction and Development (EBRD) by analogy method, taking into account the degree of meteorological vulnerability of the territory of the country, showed that currently the economy of Ukraine loses an average USD 275 million (in 2005 prices) due to direct damage from floods and drought. The absolute value of prevented loss (more than $ 127 million) was obtained on the basis of the estimated loss ratio, which was 0.317 for Ukraine and is lower than for the world economy (0.45). The estimated value of the annual economic effect for hydrometeorological activity was about $ 27 million, which indicates that the effect of preventing loss from hydrometeorological disasters is almost twice the amount of funding for the hydrometeorological service.

The Audit of the Accounting Chamber of Ukraine has confirmed, that the measures of the state target programs in 2017, which provided for the solution of the logistical support for the SES of Ukraine activity as a component of the national hydrometeorological service (in accordance with the Law of Ukraine "On Hydrometeorological Activity" (part one of Article 23), through the absence of budgetary allocations for capital expenditures in 2006 - 2015 were not actually implemented (Report,2018).

There is no relevant state target program after 2017, which is in violation of the above law.
Therefore, economic and financial barriers are the biggest obstacles to implement the technology under consideration.

For the successful operation of technology in Ukraine, it is necessary to equip a hydrometeorological service, or other institutions, which will be entrusted with the implementation of technology, modern technological equipment for receiving, processing data of terrestrial and satellite monitoring. It is also necessary to purchase modern software (meteorological and hydrological models, data processing programs, and other software products). Meeting these requirements is also a financial barrier.

2.3.2.2. Non-financial barriers

An important legislative barrier to technology implementation is the lack of sufficient regulatory legislative framework. Despite the considerable work being done in Ukraine on regulatory, institutional, organizational, scientific and other support for the implementation of the concept for drought and desertification, in practice the results of these activities have no significant economic and environmental impact.

The government's recent steps in this direction include:

- The approval of the Concept for Combating Land Degradation and Desertification (CMU Order No. 1024-p of 22.10.2014);

- The adoption of the National Action Plan for Combating Land Degradation and Desertification (hereinafter referred to as NAP) (CMU Decree No. 271-p of 30.03.2016);
- The establishment of the Coordination Council for Combating Land Degradation and Desertification (CMU Resolution No.20 of 18.01.2017);
- Ukraine's accession, among other 114 countries, to the Program of Support for Setting Voluntary National Task for Achieving Neutral Levels of Land Degradation (NLDCs) initiated by the Secretariat of the Concept of Drought and Desertification.

2018 was the developed project of the Law " Sustainable development strategy of Ukraine by 2030". This law provides for the creation of systems for the balanced production of food and the introduction of methods for agriculture that allow to increase the sustainability and productivity and increase production volumes, promote the conservation of ecosystems, strengthen an ability to adapt to climate change, extreme weather events, drought, flood and gradually improve the quality of land and soil.

There are also legislative barriers to the implementation of satellite monitoring technologies, which are an integral part of drought assessment technology due to the lack of a legal framework in Ukraine for such work (Shelestov at al.,2017).

Lack of long-term satellite, meteorological and hydrological data sets. The availability and coverage of various ground as well as remote sensing data such as satellite imagery and radar-based data are insufficient. Access in real-time or near real-time to satellite information is limited. The delay in the receipt of information from satellite “Sentinel” reaches 5 days, and from satellite “Landsat” reaches in 14-16 days.

To overcome this barrier, it is necessary to undertake organizational measures within the structures of meteorological monitoring in order to create modern satellite, meteorological and hydrological data bases. SESU has not modern satellite, meteorological and hydrological data bases in available format for the operation of drought risk assessment technology.

An important non-financial barrier is **human potential.** The successful and long-term operation of the technology requires the presence of a number of highly qualified specialists with specialization in meteorology, hydrology, monitoring, GIS technologies, mapping, IT technologies that could work with large databases, models and modern equipment.

Lack of awareness about benefits of technology - a barrier that will impede the application of technology to the benefit of the various sectors of the dependent economy and its diffusion.

Inefficient insurance system: ignorance of the benefits of technology. Weather indices-based insurance is the most suitable for agricultural production in the regions of Ukraine where drought loss is widespread. However, this type of insurance is not yet widely popular, primarily because of inadequate information and logistical support of domestic hydrometeorological services and lack of understanding by farmers for the need for crop insurance.

Tree of logical problem analysis (problem tree) for this technology is presented in the Fig. WII - 04.

Experts were suggested to assess the significance of each barrier by attributing scores from 1 to 5 to each barrier, where 1 is insignificant barrier and 5 – very significant barrier. Later, the obtained scores were summed up for each barrier, allowing national consultants to distinguish the importance of each barrier. The results of the barrier’s determinations are shown in the table 2.6.

Table 2.6. List of barriers by level of ranking for drought hazard assessment and mapping technology

Significance	Identified barriers	Description of barrier
Very important	Lack of awareness about benefits of technology	1. Low awareness of the economic benefits for technology among government risk's management authorities. 2. Low awareness about benefits of technology between owners of agricultural enterprises and insurance companies. 3. Low media interest in disseminating technology information.
	Inefficient insurance system: ignorance of the benefits of technology	1. Lack of understanding by farmers for the need for crop insurance on the basis of weather indices 2. Insurance companies lack the mechanisms to account for regulating the benefits of using technology
Important	High financial costs	1. Costs for the modernization of technological equipment for terrestrial meteorological and hydrological monitoring. 2. Costs for modernization equipment for data receiving and processing. 3. Costs for retraining specialists for technology operating
	Lack of long-term satellite, hydrometeorological data sets	1. Access in real-time or near real-time to satellite information is limited. 2. Monitoring data bases are not available, or limited available.
	Lack of state support of hydrometeorological monitoring	1.Low level of state financing of hydrometeorological monitoring 2.Low financing is reason of poor quality of the observation data.
	Imperfect legislative and regulatory framework for technology implementation	1. Lack of sufficient regulatory legislative framework. 2. Legislation improving activities has not yet significant economic and environmental impact. 3. Lack of a legal framework for the implementation of satellite monitoring technologies.
	Lack of experts for modelling and forecasting of floods	1. Lack of highly qualified specialists with specialization in meteorology, hydrology, monitoring, GIS technologies, mapping, IT

		technologies that could work with large databases, models and modern equipment. 2. Low level of salary in the monitoring's department of SESU: service is not attractive for highly qualified specialists.
Less important	Expensive hardware components of technology	Hardware components are required to be changed for the operation of technology's needs
	Expensive licenses for software components	Lack of modern software components of technology

2.3.3. Identified measures

2.3.3.1. Economic and financial measures

The main barriers on the way to technology implementation are economic and financial barrier that are associated with the need to modernize the system of hydro-meteorological monitoring. The lack of government funding of NMHS and the difficult economic situation in the country requires to find non-standard ways to overcome this barrier.

NMHSs of Ukraine is a member of the World Meteorological Organization, so the implementation of the WMO service delivery strategy (WMO, 2014) can be a very real mechanism for overcoming financial and economic barriers. The strategy explains the importance of service delivery; defines the four stages of a continuous, cyclic process for developing and delivering services and the elements necessary for moving towards more service-oriented culture; and describes practices to strengthen service delivery. The goal of the Strategy is to help NMHSs to raise standards of service delivery in the provision of products and services to users and customers.

On the basis of the improved quality of services, implement commercial activities that will generate income, additional to the fund provided by the state.

IBRD experts have established (Evaluating, 2007) that the modernization of hydrometeorological monitoring of Ukraine requires to attract investments of USD 82 million, which will pay off in 2 years, and after 7 years their efficiency exceeds to 300%.
The index of effectiveness of the investments is needed for the technical modernization and development of the National Hydrometeorological Service of Ukraine ranges from 1: 4.1 to 1: 10.8: each dollar that will be invested in monitoring upgrades can benefit from $ 4 to $ 11 at the expense of the warning loss from natural meteorological phenomena. The modernization of monitoring and use of modern technologies for drought and flood risk assessment and mapping will allow to get considerable economic effect in different sectors of the economy, which depend on the weather.

There are currently no clear instructions in the "Barrier Guidebook" (2016), nor in "The Economics of Adaptation. Concepts, Methods and Examples" for the economic calculations of non-marketing technologies, so the cost of implementing it in Ukraine can be fulfilled only approximately.

For example, the application of drought's risk assessment and mapping technology on the basis of modernized monitoring would reduce crop loss in drought annually by $ 950 million to $ 1400 million (Evaluating, 2007). This means that every year Ukraine will additionally benefit from the implementation of this technology in the agricultural sector at 2.1 -3.1% of GDP.

2.3.3.2. Non-financial measures

Full access to EUMETNET space monitoring databases. EUMETNET offers a framework for EUMETNET Member NMHSs to collaborate on activities in the field of Observing Systems. Ukraine is the Associate member of EU and can join the organization and gain access to space monitoring information. It will be an effective measure that will help to overcome operational quality and efficiency for gaps/ barriers. This will bring the whole work and system to new standards and will broaden access to new resources and collaboration. Firstly, the rapid acquisition of environmental monitoring data on the basis of satellite technologies will allow the rapid assessment of soil moisture, the moisture content of vegetation and soil in large areas, and therefore warn in advance of the need for irrigation or other measures to prevent drought. Secondly, for drought-affected areas on the basis of satellite data, it is possible to quickly map the area of crop loss and to estimate the damage caused by the drought as accurately as possible, as well as the amount of assistance required for farmers.

To overcome the legal barrier, it is necessary to create a regulatory framework for technology implementation. Legislative changes are required to create a favorable climate for overcoming financial and bureaucratic obstacles to the implementation of appropriate technology, and oblige stakeholders and insurance companies to use technology in order to avoid economic loss from doing business and maximizing profits.

The Coordination Council on Land Degradation and Desertification should include in the NAP a list of measures for the implementation of drought hazard assessment and mapping technology, its dissemination and exploitation of results and the creation of a regulatory framework to overcome financial and bureaucratic obstacles to its implementation.

Overcoming this barrier could be facilitated by the adoption of the Law "Sustainable development strategy of Ukraine by 2030", whose project was developed in 2018. This law provides for the creation of systems of balanced production of food and the introduction of methods of agriculture that allow to increase the sustainability and productivity and increase production volumes, promote the conservation of ecosystems, strengthen the ability to adapt to climate change, extreme weather events, droughts, floods and gradually improve the quality of land and soil.

The implementation of drought's hazard assessment and mapping technology in Ukraine are required to create a legal framework the implementation of satellite monitoring technologies.

Disseminating information about the benefits of technology will also contribute to its dissemination and efficiency. Removing the barrier requires awareness campaigns carried out by the authorities, the media and NGOs. To remove the barrier, it is necessary to intensify the campaign to highlight the activities of the hydro-meteorological service, types of forecasting and warning opportunities of the phenomena, the benefits of using early forecast, government, business and the media.

A shortage of qualified personnel can be corrected by the training of employees in the middle system of vocational education and higher education is observed. The provision of experts in the field should be made by the higher school, retraining and advanced training of specialized organization or investors. The training of such specialists can be organized in Ukrainian universities, where there are a sufficient number of highly qualified teachers from different fields of knowledge and a material and technical base for training.

On the basis of existing competencies of NMHS staff members, areas requiring additional training shall be identified and individual training plans shall be compiled. It is proposed that the plans follow the recommendations for competence development provided by the WMO Technical Commissions. The learning success shall be evaluated according to the WMO competency assessment.

SESU is required to reform job's payment system (increasing of monthly payment) to involve skilled people to monitor department.

Increasing of efficiency of insurance system. Following the modernization of the hydrometeorological monitoring service and the implementation of the flood risk assessment and mapping technology, a powerful awareness campaign for stakeholders and insurance companies should be undertaken to clarify the benefits of using the technology and to develop regulatory mechanisms for the use of technology by stakeholders and insurance companies.

Insurance companies should be able to adequately assess their own benefits from using drought's hazard assessment and mapping technology for development and implementation of modern insurance approaches on the base of climatic indexes. Can we use, for example, the current crop insurance system for drought risks in Austria (Agricultural, 2017)?

This system is characterized by dependence of insurance rate on the crops' sensitivity to insurable risks (drought damage) and the local hazard probability (e.g. the chance of drought) and exposure. Tariffs are calculated separately for each municipality. In subsequent years, premiums are determined by a bonus-malus-system on the basis of the loss ratio of the preceding 10 years of insurance. This means if compensation was paid in the insurance previous period, the premium may increase by up to 20% of the basic premium. If the loss ratio falls below the actual premium level, the premium is lowered automatically. The lowest premium level (60% of the basic premium) can be reached after a minimum of three years of insurance. Certain on-farm risk's reduction measures are considered in the premium calculation. The same reference location that serves as a reference for hail risk is used for the drought index. For drought index premiums, the bonus-malus-system is used to calculate premiums independently from other insured risks.

Results of measuring identification are shown in form of the list of barriers and identified measures to overcome determined barriers on the implementation and dissemination of drought hazard assessment and mapping technology (Table 2.7) and on the Fig.WII-05 in form of objective tree.

Table 2.7. List of barriers and measures to overcome determined barriers on implementation and dissemination of drought hazard assessment and mapping technology

Determined barriers	Measures identified to overcome determined barriers
Lack of state support of hydrometeorological monitoring	Increasing of state support for hydrometeorological monitoring, search for investment, financial credits, funding
Lack of long-term satellite, meteorological and hydrological data sets	Joining the NMHS of Ukraine to the EUMETNET. The creation of satellite, meteorological and hydrological data base
Lack of experts for drought assessment and mapping	Training of experts for drought assessment and mapping

High financial costs	The implementation of the WMO service delivery strategy. Search for financial support from donors and funds
Expensive hardware components of technology	Search for technical aid possibilities
Expensive licenses for software components, detailed topography maps	Purchase annual licenses, creating conditions for sharing of software, maps
Imperfect legislative and regulatory framework for technology implementation	The development of legislative and regulatory framework for technology implementation
Lack of awareness about benefits of technology	Wide awareness about benefits of technology
Non-efficiency insurance system: ignorance of the benefits of technology	Increasing efficiency of insurance system

2.4. Barrier analysis and possible enabling measures - Flood risk assessment and mapping technology

2.4.1. The General description of technology

Flood's hazard assessment and mapping are used to identify areas at the risk of flooding, and consequently to improve flood's risk management and disaster preparedness. Flood hazard assessments and maps typically look at the expected extent and depth of flooding in a given location, on the basis of various scenarios.

There are several definitions of term "flood" in the world literature (Díez-Herrero,2009):

1. According to Webster's unabridged dictionary, flood signifies "a rising and spreading of water over land not usually submerged". It is synonymous with inundation, from the Latin verb inundate.
2. The Spanish Basic Directive on Planning Civil Protection Against Flood Risks (MJI, 1995) defines a flood as the temporary submersion of normally dry lands as a result of an unusual and more or less sudden flow of a quantity of water which exceeds to a given zone's usual quantity.
3. The Federal Emergency Management Agency (FEMA) in the United States further quantifies the surface subject to flooding in order to consider it a flood: "A general and temporary condition of partial or complete inundation of two or more acres (0.81 ha) of normally dry land area or of two or more properties", that is, an excess of water (or mud) over land that is normally dry.
4. The European Community Directive 2007/60/EC on the assessment and management of flood risks defines flooding as "the temporary covering by water of land not normally covered by water" (Article 2.1).

Flood risk, therefore, refers to the potential situation of loss or harm to persons, material belongings or services as a result of the covering of normally dry areas with flood, which are assigned a specific severity (intensity and magnitude) and frequency or probability of occurrence.

Flood risk can have various aspects. M. Stock (Stock, 1996) has termed the interdependency of different flood risk components "the cascade of flood risk" (Fig.2.6).

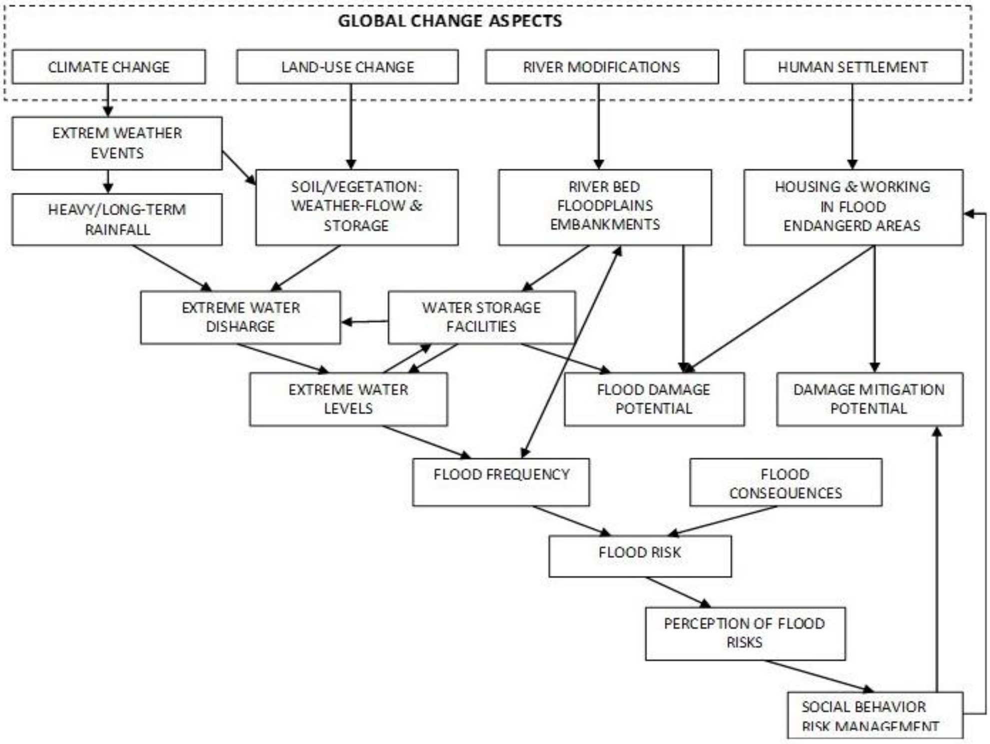


Figure 2.6. Causes, effects and consequences of floods: "Cascade of flood risk" (after M. Stock[41]).

This cascade includes the flood-relevant aspects of global change: climate change, change in land use und land cover, modification to the river morphology and the channel system, as well as increase in human settlements. These changes of environmental conditions affect the flood risk at different levels. For example, by altering the retention capacity of river basins, by changing both the retention capacity and the potential damage in floodplains adjacent the river, and by increasing the vulnerability due to settlement in flood endangered areas. Subsequently, flood risk is influenced by natural (climate; river basin morphology) and man-made (river channelization; urbanization) factors influencing the frequency of floods and social/economic factors influencing their consequences.

An integrated analysis, covering the cause-effect chain of precipitation-runoff generation – runoff concentration – flood wave propagation – (routing) -inundation – flood damage, would allow for a comparative assessment of the various flood-triggering and damage-causing factors.

Therefore, a state-of-the art evaluation on flood risk should include all relevant levels of flood risk composition, both the aspects of naturally induced hazard and vulnerability due to the activity of humans (Plate,2002).

The European Flood Directive (Article 2.2) defines it as the "combination of the probability of a flood's occurrence and the potential negative effects on human health, the environment, cultural heritage and economic activity associated with flood".

There are essentially two types of natural floods: surface flooding ("inland" flooding), in which fresh waters inundated areas of the inner parts of continents; and coastal flooding, in which sea waters or lake-marsh waters inundate the areas along the edge of surface regions.

Surface (river) flooding is prevailing type of flooding in Ukraine. Flood-prone regions of Ukraine (Fig.2.7) are located in the catchments of different Carpathian inflows in the Dniester, in the area of some Danube tributaries as well tributaries of the Prypyat (Dnipro) in the northwest of the country (ICPDR,2005; ICPDR,2011).

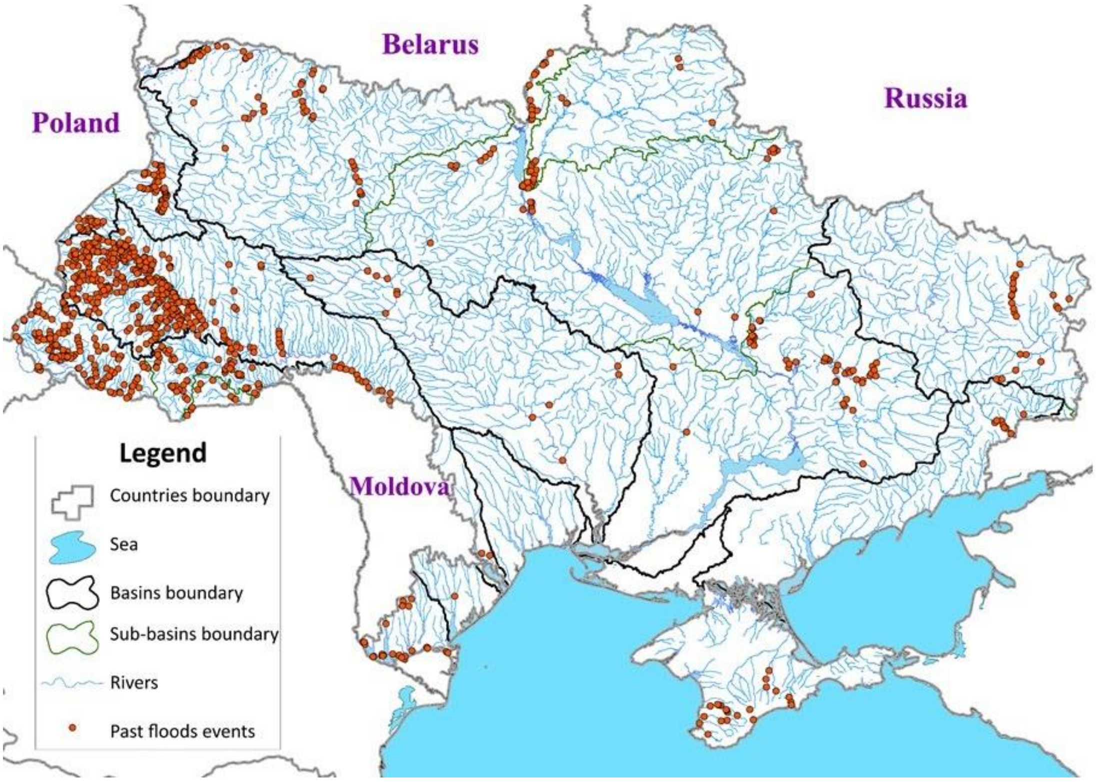


Figure 2.7. Distribution of past significant floods with signs of an emergency (Total:899, in Danube basin: 247 899 flood events (Danko at al., 2019)

In the last 20 years, in Ukraine, significant floods that have led to emergencies have been observed in 1995, 1998, 2001, 2008, 2010. Annual average flood loss in 1995-1998 amounted to more than UAH 900 million, in 1999-2007 more than UAH 1.5 billion, in 2008-2010 - about UAH 6 billion.

Only from 2000 year more than 280 emergency flood events were in Ukraine]: loss from flood – 6 203 750 ₴ or 228 079 €; expenses for liquidation flood events with adverse consequences – 65 419 925 ₴ or 2 405 144 €.

Flood in the Carpathians is natural phenomena common to this territory (Didovets at al.,2019). They are determined here by the frequency, intensity of development and simultaneous spread on a large area (up to 10-30 thousand km^2), often with significant destructive consequences.

There were several destructive floods in recent decades (in 1998, 2001 and 2008) in Ukraine. One of the biggest and destructive floods occurred in the Carpathian region and surrounding areas within Ukraine, Moldova and Romania at the end of July 2008, causing 47 fatalities and evacuation of about 40 000 people. Over 40.000 houses and 33.000 ha of farmland were flooded in Ukraine (International Commission, 2009). In the Carpathian rivers, rain and snow-rain flood of different heights are repeated 3-8 times a year. But they are particularly threatening in periods of high-water availability due to global atmospheric circulation. Studies have revealed the alternation of periods of high water in the rivers of the Western region of Ukraine and cyclic components in the structure of long-run fluctuations of the river runoff of the Carpathian region and the Right Bank of the Pripyat. During these periods, dangerous rain flood occurred with the appearance of cycles in 3-4 and 6-8 years.

To implement at the Association Agreement between Ukraine on the one hand and the European Union on the other hand, one of the priorities for the environmental policy of Ukraine is the harmonization of the water legislation of Ukraine with the EU legislation, in particular, with Directive No. 2000/60 / EC "On the establishment of the Community framework for activities in the field of water policy "(Water Framework Directive, WFD) and Directive 2007/60 / EC" On Flood Assessment and Management "(Flood Directive), the main principles of which are the implementation of an integrated basin water management model and flood management.

Flood’s hazard assessment and mapping technology consists of 4 stages (Fig.2.8):
1. The collection of information about areas at risk of flooding;
2. The preparation of information, tools and data preprocessing;
3. Flood modelling and scenario design;
4. Flood Hazard Assessment/Risk Mapping.

In the first stage of the technology, all kinds of the information required for flood’s risk assessment must be collected. Data for flood’s risk assessments include both field measurements and remote sensing data (Shevchuk at al.2019). Observational data sources used in flood hazard assessments are either station data (e.g., meteorological stations, discharge gauging stations) or gridded data (e.g., reanalysis data, satellite data). In hydrological flood studies, the most commonly used data are streamflow measurements.

Next steps in this technology stage for flood’s hazard assessment are:
1. a preparation of detailed topographical and specialized maps and digital elevation models of the river basin district at the appropriate scale including the borders of the river basins, sub-basins and, where existing, coastal areas, showing topography and land use;
2. a description of the floods which have occurred in the past and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent and conveyance routes and an assessment of the adverse impacts they have entailed;
3. a description of the significant floods which have occurred in the past, where significant adverse consequences of similar future events might be envisaged.

In the second stage of the technology, there must be the preparation of information, chose of hydrological models, mapping tools and data pre-processing.
The most common hydrological models are MIKE FLOOD, MIKE 11, MIKE 21, InfoWorks RS, LISFLOOD-FP.

MIKE FLOOD (Flood modelling,2020) is highly efficient and flexible for riverine flood modelling. Flood mapping, risk and hazard analysis of flood incidents from extreme upstream inflows as well as local high intensity rainfall in surrounding catchments are perfectly modelled with MIKE FLOOD. MIKE FLOOD enables flood simulations at multiple scales from river basins to local cells and flood-prone areas along the river.

Riverine flood modelling commonly consists of a coupled model of 1D river component, MIKE HYDRO River, and the 2D overland flow component, MIKE 21. The flexibility of the coupled 1D/2D models provides numerous opportunities to analyse complex flooding issues, such as:
- Conveyance problems due to improper maintenance of vegetation
- Limited upstream flood storage capacity
- Crossing infrastructures reducing flow capacity in rivers and floodplains
- Flood preventions through optimized structure operation in reservoirs

- Flood impacts from dam break or levee breach failures
- Land use changes
- Climate change flood risk impacts

Riverine flood modelling with MIKE FLOOD combines river model component, MIKE 11, and our 2D surface modelling component, MIKE 21. Riverine modelling can also conduct with detailed hydrological components and groundwater and surface water interaction using MIKE SHE packages. This includes a surface flood component and a linkage to MIKE 11.

The lack of reliable data to calibrate and validate models is often a challenge, especially in ungauged catchments or remote parts of the world. This can often be overcome by using remote sensing information input. Satellite images provide valuable information across time and space, about flood events. Satellites can be used to generate up-to-date maps of flooding.

InfoWorks RS (InfoWorks RS, 2020) is a river modelling software for open channels, floodplains, embankments and hydraulic structures. It combines in a single environment a 1D-2D simulation engine, a geographical analysis and a relative database. InfoWorks RS can be used for accurate and timely flood forecasts and risk assessments. It can accurately simulate rainfall and storm events to evaluate the preparedness and plans of action before flooding occurs. Advanced 1D/2D modeling provides a detailed representation, in case flooding may occur, when, and the severity of the flood.

LISFLOOD-FP (LISFLOOD-FP, 2020) is a two-dimensional hydrodynamic model specifically designed to simulate floodplain inundation in a computationally efficient manner in complex topography. It is capable of simulating grids up to 106 cells for dynamic flood events and can take advantage of new sources of terrain information from remote sensing techniques such as airborne laser altimetry and satellite interferometric radar. The model predicts water depths in each grid cell at each time step, and hence can simulate the dynamic propagation of flood waves over fluvial, coastal and estuarine floodplains. It is a non-commercial, research code, which has been developed as part of an effort to improve our fundamental understanding of flood hydraulics, flood inundation prediction and flood risk assessment.
By data pre-processing, we can actually analyze the hydrograph of river discharge after hydrological method. Flood is an event with abnormally high discharges recorded at a particular point or reach in the stream, then the characterization of these abnormal discharges with respect to time, i.e. establishing the flood hydrograph corresponding to the event, will be of fundamental importance. Within this hydrograph, we can study the flood's elements (peak discharge, rising limb, falling limb, and lag time), components (surface runoff, direct runoff and subsurface runoff and baseflow) and characteristic time, in relation to the corresponding hydrograph, and then assign an occurrence probability to it.

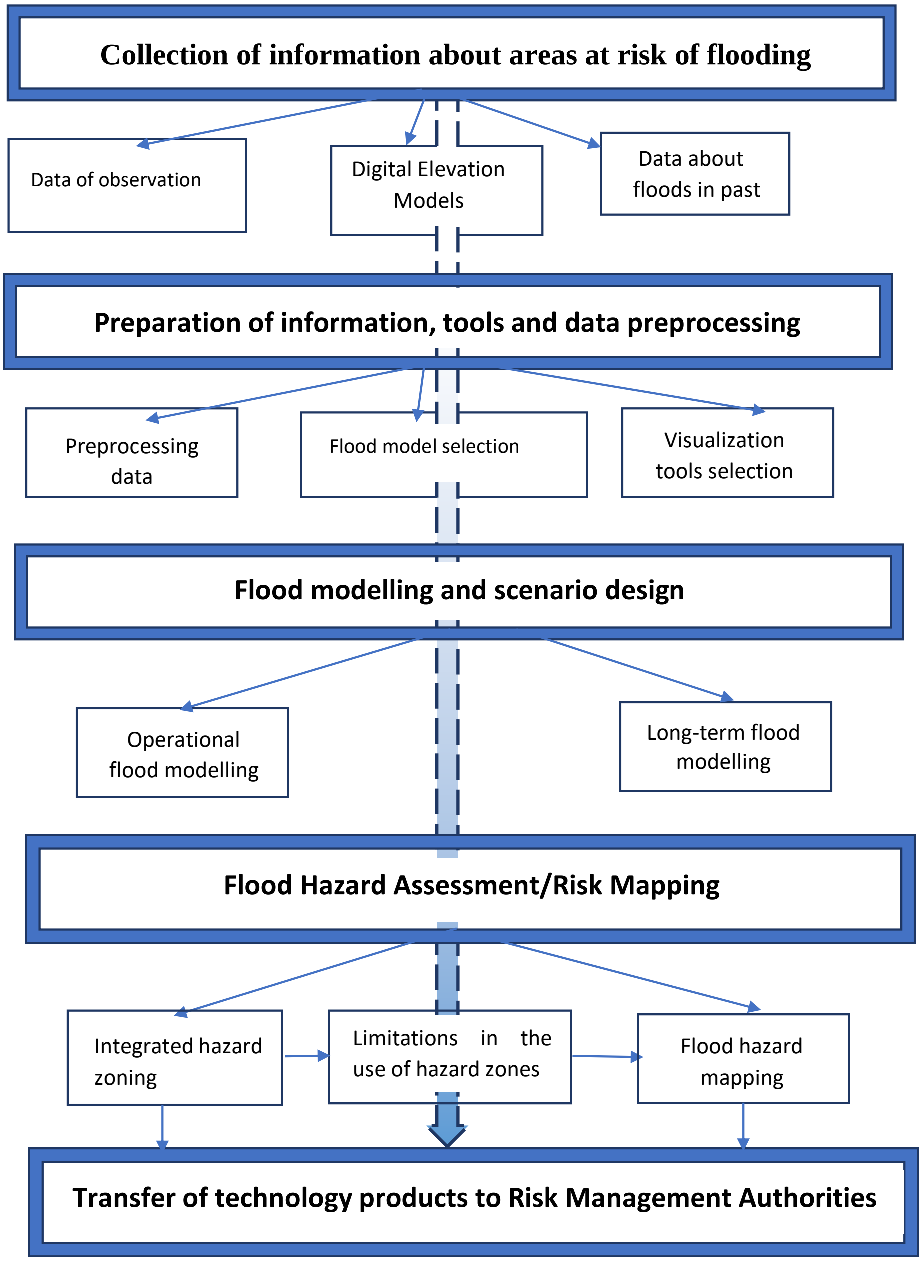


Figure 2.8. Technological structure of flood risk assessment and mapping technology

In the third stage, there must be scenario design and flood modelling.

DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks foresees the following scenarios:

(a) floods with a low probability, or extreme event scenarios;
(b) floods with a medium probability (likely return period ≥ 100 years);
(c) floods with a high probability, where appropriate according to the following scenarios:
(a) floods with a low probability, or extreme event scenarios;
(b) floods with a medium probability (likely return period ≥ 100 years);
(c) floods with a high probability, in case it is appropriate.

In the fourth stage an assessment (Flood Hazard Assessment/Risk Mapping), the assessment shall include at least the potential adverse consequences of future flood for human health, the environment, cultural heritage and economic activity, taking into account as far as possible issues such as the topography, the position of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas, the effectiveness of defense infrastructures for existing man-made flood, the position of populated areas, areas of economic activity and long-term developments including impacts of climate change on the occurrence of flood.

For flood hazard visualization, we must use the creation of flood hazard maps, which shall cover the geographical areas which could be flooded according to the following scenarios, which have been chosen in the third stage of technology (Fig.2.9) Flood hazard mapping is a basic component in flood risk analysis studies, as it permits the effective evaluation of the spatial distribution of the various elements for severity (such as water surface level, flow velocity, sediment transport, or characteristic times) and frequency (return periods or exceedance probability) of the flood phenomenon. Furthermore, they offer the utility of being able to link the maps and their associated databases to exposure and vulnerability maps in order to analyze and predict risk in an integrated manner by using such tools as geographic information systems (GIS). Hazard can be mapped in three zones (high, medium, and low) for which boundaries and usage restrictions must be established. Likewise, different tools may be used to prepare these maps, both for hazard analysis and integrating risk factors.

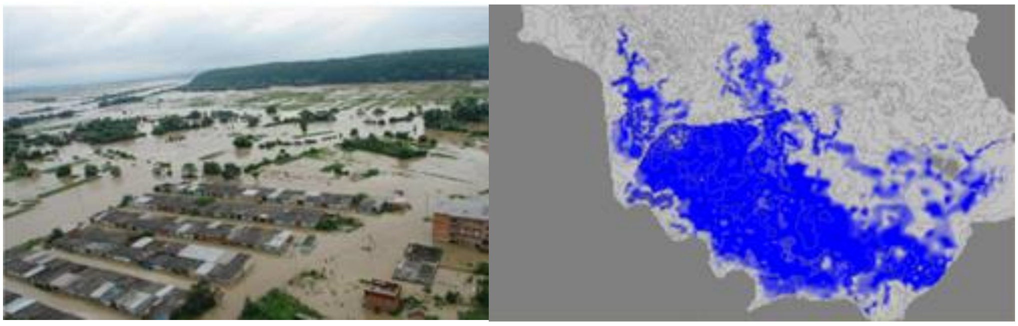


Figure 2.9. The flooded area and GIS simulation for the development of flood situation in case of dyke breach in the Tisza river basin (Ukraine) (Babych, 2020)

2.4.2. Identification of barriers for technology

Flood's risk assessment and mapping technology according to its relationship to the market belongs to subcategory "other non-market goods" in category "non-market goods". Usually the category of "other nonmarket goods" presents non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs. These technologies are not transferred as part of a market, but within a public non-commercial domain.

For the technology of non-market goods, such as flood risk assessment and mapping, drought risk assessment and mapping, barriers may be identified with the support of a cost benefit analysis for the social and environmental costs of technologies.

According to Barrier guidebook, non-market technologies are not traded in the marketplace and most often financed by public institutions or by donors rather than by users, their competitiveness should, in general, be understood in a broader social and environmental context.

The identification of barriers for flood's risk assessment and mapping is made in analogy with the previous technology – drought's risk assessment and mapping. For the identification of economic and financial barriers was used tool of logical problem analysis (LPA). This tool helped to identify of major problems in the transfer of technology, a hierarchy of barriers and relevant reasons, to build the tree of logical problem, which indicated the main relationships between causes and effects, to find logical structure and relationship with external factors.

2.4.2.1. Economic and financial barriers

The economic and financial barriers to implement flood's risk assessment and mapping technology are similar to the drought's hazard assessment and mapping technology barriers described in detail in Section 2.3.2.1.

A short list of these barriers can be summarized as follows:

1. The current unstable economic and financial situation in Ukraine due to the war in eastern Ukraine, which has led to the loss of a large number of budget-filling industries in the Donbas region and Russia's military expansion into the Crimea, which led not only to the loss of administrative integrity and disruption of economic stability, but also to indirect and unplanned budget expenditures related to the restructuring of industrial and territorial complexes, accommodation of war refugees, etc. For this reason, in recent years, public spending on environmental issues, research, education has declined significantly.
2. The low level of technical equipment of the system of hydrometeorological monitoring requires considerable investment for ensuring high quality hydrological and meteorological data required for the implementation and functioning of the flood's risk assessment and mapping technology.

Most of river basins are equipped with insufficient gauging stations for rainfall, water level and streamflow observations. The measuring equipment, gauges and data transferring instruments have deficient technology. A significant drawback of the Hydrometeorological Monitoring Service in Ukraine is the practically lack of automated technical complexes for measuring meteorological and hydrological parameters necessary for flood's assessment and mapping. The level of use of remote means for obtaining information is extremely low, there are practically no modern Doppler radars, insufficient level of use of information of meteorological satellites.

Using remotely-sensed data for real-time flood forecasting requires high-performance computing resources for data management and integration, model simulation, and further processing which will, however, necessitate more investments in implementation this technology. For instance, the detection of flash floods remains a major challenge even though this kind of flood can be detected by using real-time rainfall observation (e.g. meteorological radars) and real-time upstream water level information. The technology is not available everywhere, not even in few developed countries. Another common technical issue is the performance of the models used for flood forecasting. In operational flood forecasting and warning, modeling related challenges involve in improving the accuracy of forecasts by accounting for uncertainties in input data, modeling approaches, model simplifications, and the output's quantification.

These factors cause the lag of Ukraine's hydrometeorological service from the services of the leading countries in the world, and deteriorate the quality of the observation data in terms of the implementation of flood risk assessment and mapping this phenomenon.

2.4.2.2. Non-financial barriers

An important legislative barrier to technology implementation is the lack of sufficient regulatory framework. The implementation of Directive 2007/60 / EC (Flood Directive) in Ukraine is part of a global reform of the implementation for integrated water resource management on the basis of the basin principle.[21] In implementation process, there were changed Ukrainian Legislations (changes of Water Code of Ukraine); the identification of the appropriate competent authority (Ministry of Interior of Ukraine, The State Emergency Service of Ukraine); developed normative acts (Methods of preliminary flood's risks assessment (PFRA). Next steps of implementation are the creation of methods for development flood risk maps and flood hazard maps, template of flood risk management plan (FRMP), preliminary flood's risks assessment (for

9 River basin districts of Ukraine (RBD). But unfortunately, these legislative changes have not yet created a favorable climate for overcoming financial and bureaucratic obstacles to the implementation of the technology.

There are also legislative barriers to the implementation of satellite monitoring technologies, which are an integral part of flood hazard assessment technology due to the lack of a legal framework in Ukraine for such work (Shelestov at al., 2017).

Lack of long-term satellite, meteorological and hydrological data sets, spatial data for mapping. There is the inadequate and poor management of hydrological networks and/or temporary shut-down due to equipment damage, weather-related or financial issues impact subsequent challenges such as discrete and short records of data, poor data quality, and modeling related uncertainty. Multi-decadal continuous data records are required for producing robust flood models, model forecasts, and hazard map preparation.

The availability and coverage of various ground as well as remote sensing data such as satellite imagery and radar-based data are insufficient. Access in real-time or near real-time to satellite information is limited. Delay in the receipt of information from satellite “Sentinel” reaches 5 days, and from satellite “Landsat” reaches 14-16 days.

There is inadequate hydrological network’s coverage for monitoring of floods i.e., un-gauged or poorly gauged sites, adds to inaccuracy of flood assessment.

The acquisition of spatial data required for flood forecasting and risk mapping - such as land-use, population distribution, or soil moisture - are problematic, as some of these data sets are not updated regularly enough to be compatible with flood forecasters’ requirements.

Spatial data products, although accessible freely and available in near real-time, are under-utilised by technology; ground observations remain the common practice to detect floods. Using remotely-sensed data for real-time flood forecasting requires high-performance computing resources for data management and integration, model simulation, and further processing and mapping.

An important non-financial barrier is human potential. 74% of the flood forecasting personnel confirms that their centers do not have the experts and staff capable to integrate data, perform forecasts, and disseminate information (Perera,2019). The successful and long-term operation of the technology requires the presence of a number of highly qualified specialists with specialization in meteorology, hydrology, monitoring, GIS technologies, mapping, IT technologies that could work with large databases, models and modern equipment.

Lack of awareness about benefits of technology, it is a barrier that will prevent the use of technology to the benefit of the various weather-dependent industries and its dissemination. There is lack of new communication channels for better connection with end users and public sector.

Inefficient insurance system: ignorance of the benefits of technology in Ukraine, the insurance business still does not take advantage of the use of modern technologies for flood’s risk assessment. The insurance procedure is optional. The population is not motivated for compulsory insurance, since the state compensates for the flood damage from the state budget. Those flood victims who received compensation from the insurance company are not eligible to receive assistance from the state.

Tree of logical problem analysis (problem tree) for this technology is presented in the Fig.WII-06.

Similarly, to the two above described technologies, experts were suggested to assess the significance of each barrier by attributing scores from 1 to 5 to each barrier, where 1 is insignificant barrier and 5 – very significant barrier. Later, the obtained scores were summed up for each barrier, allowing national consultants to distinguish the importance of each barrier. The results of the barriers determinations are shown in the table 2.8.

Table 2.8. The list of barriers by level of ranking for flood risk assessment and mapping technology

Significance	Identified barriers	Description of barrier
Very important	Lack of awareness about benefits of technology	1. Low awareness about use of technology to the benefit of the various weather-dependent industries. 2. Low awareness about benefits of technology between insurance companies. 3. Lack of new communication channels for better connection with end users and public sector.
	Lack of long-term satellite, meteorological and hydrological data sets	1. Access in real-time or near real-time to satellite information is limited. 2. Monitoring data bases are not available, or limited available. 3. Extremely low level of use of remote means for obtaining information
	Inefficient insurance system: ignorance of the benefits of technology	1. Insurance business still does not take advantage of the use of modern technologies of flood's risk assessment. 2. Population is not motivated for compulsory insurance, since the state compensates for the flood damage from the state budget
Important	Lack of state support of hydrometeorological monitoring; measuring equipment, gauges and data transferring and collecting instruments have deficient technology	1. Low level of state financing of hydrometeorological monitoring 2. Low financing is reason of poor quality of the observation data. 3. Temporary and periodically shut-down due to old equipment damage impact subsequent challenges such as discrete and short records of data.
	High financial costs	1. Low level of technical equipment of the system for

		hydrometeorological monitoring requires considerable investment for ensuring high quality hydrological and meteorological data. 2. Costs for automated technical complexes for measuring meteorological and hydrological parameters necessary for flood assessment and mapping. 3. Costs for modernization equipment for data receiving and processing. 4. Costs for retraining specialists for technology operating
	Lack of experts for modelling and forecasting of floods	1. Lack of the experts and staff capable to integrate data, perform forecasts, and disseminate information. 2. Low level of salary in the monitoring's department of SESU: service is not attractive for highly qualified specialists.
	Expensive hardware components of technology	Using remotely-sensed data for real-time flood forecasting requires high-performance computing resources for data management and integration, model simulation, and further processing which will, however, necessitate more investments in implementation this technology.
Less important	Imperfect legislative and regulatory framework for technology implementation	1. Lack of sufficient regulatory national framework for creation of flood's risk management plan (FRMP), and preliminary flood risks assessment (for 9 River basin districts of Ukraine). 2. Legislation improving activities have not yet significant economic and environmental impact. 3. Lack of legal framework for satellite technologies implementation.
	Expensive licenses for software components, the Numerical Weather Predictions models, hydrologic models, detailed topography maps	Lack of modern software components of technology

2.4.3 Identified measures

2.4.3.1 Economic and financial measures

Flood's risk assessment and mapping belong to the group of technologies provided by public institutions and to the category of non-market goods and usually financed by donors and public entities. This group of goods is usually free of charge. Implementing the service is mainly dependent on access to finance and a government decision to implement it. Barriers to its long-term sustainability are poor management skills and traditions, low levels of technical capacity and limited access to required skills and equipment at the institutional level in the concerned countries.

For the successful operation of technology in Ukraine, it is necessary:
- ***to equip a national NMHS***, or other institutions, which will be entrusted with the implementation of technology, ***with modern technological equipment*** for receiving, processing and storing data of terrestrial and satellite monitoring;
- ***to purchase modern software*** (meteorological and hydrological models, data processing programs, digital terrain models, other software products). Meeting these requirements is also a financial barrier;
-***to attract additional financial resources*** from external sources, possibly from the private sector, although the private sector is underdeveloped especially in rural areas, international sources. Financial resources should be involved not only in the form of a loan, but also investments, contributions of beneficiaries and holders and other stakeholders. Here, private interests with the interests of local authorities should be united. ***To attract an additional cost for implementation of the technology may help access of NMHS of Ukraine to the WMO service delivery strategy and strengthen collaboration with EFAS*** to access to innovative technologies. The implementation of the WMO service delivery strategy (WMO, 2014) can be a very real mechanism for overcoming financial and economic barriers. The goal of the Strategy is to help NMHSs to raise the standards of service delivery in the provision of products and services to users and customers. On the basis of improved quality of services, there should be the implementation of commercial activities that will generate income, additional to the state provided funding.

It is believed that there is currently insufficient information to obtain unit costs or cost curves to estimate the cost of implementation of technologies similar to flood assessment and mapping technology[19]. But some case studies and example projects are provided to demonstrate cost elements required.

The implementation of technology requires the following types of costs:
- Enabling costs;
- Capital costs;
- Maintenance costs.

Enabling costs associated with setting up technology infrastructure and administration costs where these are currently not available.

There is capital cost associated with hydrometric installation, development of forecasting models, software and hardware costs and dissemination systems.

There is maintenance cost associated with operational running costs and national, regional and local training and exercises. Costs remain low with comparison to measures to reduce the extent of flooding.

Capital cost on national level. EBRD experts have established that the modernization of hydrometeorological monitoring in Ukraine requires attracting investments of USD 82 million, which will pay off in 2 years, and after 7 years, their efficiency will exceed to 300%. The cost effectiveness of investments required for the technical modernization and development for the National Hydrometeorological Service of Ukraine ranges from 1: 4.1 to 1: 10.8: each dollar that will be invested in monitoring upgrades can benefit from $ 4 to $ 11 at the expense of the warning losses from natural meteorological phenomena. Upgrading the monitoring and use of modern drought and flood's risk assessment and mapping technologies will also produce significant economic effects in various weather-dependent sectors of the economy. For example, the application of drought's risk assessment and mapping technology on the basis of modernized monitoring would reduce crop losses in droughts annually by $ 950 million to $ 1400 million[14]. This means that every year Ukraine will additionally benefit from the implementation of this technology in the agricultural sector at 2.1 -3.1% of GDP.

The following areas of hydrometeorological monitoring activities should be provided for:

- setting up any new organizational structures for the implementation and exploitation of flood assessment and mapping technology;
- installing, operating and maintaining hydrometric equipment;
- developing, configuring and running forecasting models;
- buying computer software and hardware to support the above operations.

Costs of developing flood forecast systems are likely to be the largest element of the capital outlay, where an existing warning and forecasting platform is available. Cost is likely to vary between £20,000 and £80,000 per scheme for project management and development of hydrological models (Cost estimation,2015). Once developed, forecast models will require configuration on the forecasting platform. This is an area that has been underestimated in the past terms of staff resources to implement and maintain forecast models. Configuration is usually undertaken in-house by the Environment Agency, but experience has shown that the cost for consultants to carry this out can be in the region of £3,000–5,000 per catchment forecast model (Cost estimation, 2015).

There are some examples of costs associated with creating and developing forecast models (Table 2.9).

Table 2.9. The review of costs for ongoing and recently set up forecasting and warning schemes in Ireland

System	Source of flood risk	Models and software used	Cost (capital and maintenance)

Munster Blackwater Mallow Initial Flood Forecasting System (IFFS)	Fluvial Fluvial	In-house development of an IFFS for the catchment. Originally spreadsheet based level correlation model Unified River Basin Simulator (URBS) rainfall run-off model; MWH Soft FloodWorks forecasting system	Standalone IFFS only: Capital €39.000 Annual maintenance €26.400 Capital €335.000 Annual maintenance €230.000
Suir Clonmel Initial Flood Forecasting System	Fluvial Fluvial	Routing model in Microsoft Excel spreadsheet URBS rainfall run-off model; FEWS software by Deltares	Capital €57.000 Annual maintenance €28.800 Capital €335.550 Annual maintenance €195.900
Bandon Flood Early Warning System (FEWS)	Fluvial	Level to level correlation model; HYDRAS 3	Capital €60.000 Annual maintenance €10.000 (preliminary estimate)
Tidewatch and Triton	Coastal	Tidewatch: Excel spreadsheet using O'Connel-Coe formula Triton: still water and wave overtopping model base on UKMO system	Capital €300.000 Annual running costs: €50.000 Major updates: €20.000 (every four years)
ICPSS	Coastal	Hydrodynamic surge and tidal model; MIKE 21 software	Costs based on trial period only: Capital €87.000 Annual running costs: €68.100
Marine Institute	Coastal	Ocean forecast model: ROMS Wave model: SWAN	Capital (hardware only) €400.000 Annual running costs: €280.000

(Cost estimation, 2015).

An approximate estimate of the amount of investment to create and develop a technology of flood’s risk assessment and mapping can be made by using the analog method. In the literature

(Perera et. al. 2019), there are some economic evaluations a very similar technology of the Flood Early Warning Systems (FEWS) (Table 2.10)

Table 2.10. Examples of investments in implementation of FEWS

Region	Area of the territory	Investment	Investment weight per km2
West Africa's Niger River basin	1.5 million km²,	USD 4 million	2,7 USD/km^2
Danube and Vistula river basins in Slovakia	a 49,000 km²	USD 34 million	694 USD/km^2

(Perera et. al. 2019)[17]

The cost of the technology we are considering can be 60-70% of the cost for the requirement of creating and developing FEWS. The difference in the cost of technology implementation can be very different. For example, in developing and least for investment in developed nations for the implementation of FEWS range from USD 5,000 in Namibia to USD 5 million in Myanmar including USD 100,000 in Nepal for an intermediate system, USD 1 million in Cambodia and USD 2.5 million in Bangladesh for advanced systems.

Software's license costs can vary significantly, but may be negligible in the case of spreadsheet or correlation models. It is anticipated that a forecasting organization will have all of the required software required for flood warning or forecasting. No additional costs are likely required, unless specific or bespoke software applications are required for a particular location or scheme. In case it is required, license costs can be obtained from flood forecasting model software suppliers, in case the required software is not currently available.

A forecasting system as very important part of flood assessment technology requires a large amount of **capital costs.** It is required to collate hydrometric and meteorological data, run forecast models and provide the necessary decision support tools to assist in the provision of the next mapping procedure. For example, for the implementation of the National Flood Forecasting System in the UK, it was used from 2002 to 2007 £15 million.

The successful implementation of the technology is not possible in the absence of modern Digital Elevation Models (DEM), because it is only possible to accurately calculate floodplain areas by combining the DEM with satellite and ground-based monitoring data. DEM with a resolution of 30 m to 50 cm costs in Europe from 3 to 15 thousand dollars for 1 km sq. Cost for creating DEM for river catchments can reach significant values in Ukraine. For example, developing DEM for transboundary Uzh river basin in frame of Project of international technical assistance of the European Union „Joint activities for the prevention of natural disasters in the transboundary Uzh river basin", Grant Contract HUSKROUA/1702/8.1/0005 of 29.08.2019) cost 200000 USD (co-financing from Ukrainian part of project; the source of funding – state budget funds of Ukraine) (Digital Terrain Model, 2019).

In the real situation, however, different countries in the UNECE region have the different possibility of drawing flood risk maps due to different levels in levels of values and the technical infrastructure in place to collect and share data modeling and mapping, as well as financial resources. Drawing up flood risk maps are very expensive and depend on the availability of data. According to Swiss estimates, the cost of flood risk mapping is around EUR 2,000 per km2 (Transboundary, 2009).

There are currently no clear instructions in the "Barrier Guidebook" (2016), nor in "The Economics of Adaptation. Concepts, Methods and Examples" for the economic calculations of non-marketing technologies, so the cost of implementing it in Ukraine can be fulfilled only approximately.

On the basis of the data that we obtained from various sources, the following calculations can be made:
1. The evaluation of loses from floods in Ukraine (Table 2.11).
Annual average flood losses in 1995-1998 amounted to more than UAH 900 million, in 1999-2007 more than UAH 1.5 billion, in 2008-2010 - about UAH 6 billion (Investopedia, 2020).

Table. 2.11. Flood loses in Ukraine during 1995-2010

Period	Period, years	Annual average flood losses, UAH billion	Exchange rate (median value), UAH/USD	Volume of losses for the period, billion USD
1995-1998	4	0,9	1,76	2,045
1999-2007	9	1,5	5	2,700
2008-2010	3	6,0	6,53	2,756
Total loses				7,5

Assuming that flood damage in Ukraine during 1995-2010 amounted to $ 7.5 billion, 1% reduction in flood damage, which could be due to the introduction of Flood's Risk Assessment and Mapping, could help save $ 75 million for the year in which the flood will occur.

To assess the feasibility of introducing technology in Ukraine, we use data (Comprehensive program, 2006) stating that impact of harmful effects of flood is observed in Ukraine in the area of 165000 km^2.

Below, we calculate the cost of Flood's Risk Assessment and Mapping technology (Table 2.12).
Table 2.12. Cost of Flood Risk Assessment and Mapping technology

Item	Costs
The modernization of hydrometeorological monitoring of Ukraine[14]	USD $82 million
The implementation of FEWS[17], 694 USD/km^2	$63,195 million (694 $/km^2*165000 km^2)
Developing of forecasting system for 6 largest rivers in UA[20]	$387000 USD (£80 000+4*£50 000+£30 000; 1£=$1.25)
Digital Elevation Models (DEM), 25 $/km2[2]	$4,125 million (25 $/km2*165000 km2)
Total	$149,707 million

Having given the high cost of implementing the Flood Risk Assessment and Mapping system ($ 149.7 million), it can pay off in 2 years (with an annual "savings" of $ 75 million). It should be borne in mind that technology can pay off in flood years, although a truly modernized hydrometeorological monitoring system will be useful even in flood-free years.

2.4.3.2. Non-financial measures

The following measures should be recommended for overcoming non-financial barriers:
- ***To create a legal regulatory framework*** for technology implementation. Legislative changes are required to create a favorable climate for overcoming financial and bureaucratic obstacles to implement the technology in question, and oblige stakeholders and insurance companies to take advantage of technology in order to avoid economic loss in doing business and increase their profits. The implementation of this technology needs the creation of the legal framework for satellite monitoring technologies.

- ***To undertake organizational measures*** within the monitoring structures of NHMS after its modernization is to create modern satellite, meteorological and hydrological data bases. The needs for spatial data is required for flood forecasting and risk mapping - such as land use, population distribution or wetlands - must be addressed at the state level by developing an imperative regulatory framework for the free provision of mapping materials for technology requirement. There is currently no such regulatory mechanism. Therefore, state organizations involved in flood assessment are forced to buy cartographic materials at the State Cartographic Research and Production Enterprise “Kartografia”. The cost of the most optimal scale maps (1: 500) is 150-200 USD / ha.
-***To prepare and carry out wide awareness campaigns*** by the authorities, the media and NGOs. It is necessary to intensify the campaign to highlight the activities of the hydro-meteorological service, types of forecasting and warning opportunities of the phenomena, the benefits of using early forecast, government, business and the media. The dissemination of the information about benefits of technology will also contribute to its effective implementation and use.

The Ministry of Energy and the Environment, the State Emergency Service, together with the Ministry of Information Policy, should launch a public awareness campaign on the use of flood assessment and mapping results to prevent flood.

-***To train personnel for technology operation*** in the middle system of vocational education and higher education. The provision of experts in the field should be made by the higher school, retraining and advanced training of specialized organization or investors. The training of such specialists can be organized in Ukrainian universities, where there are a sufficient number of highly qualified teachers from different fields of knowledge and the available material and technical base for training under the targeted state order for training such specialists.

- ***To develop of new training programs*** for training and retraining of personal. The design, review and updating of the training programs to provide staff at different levels with the advanced technology required to meet the challenges of hydro-meteorology data collection and transmission, flood forecasting, sustainable technology development and flood mapping are also very important.

Training on hydrologic data collection, transmission, achieving and retrieval techniques, methods of communication interface techniques among meteorological inputs, hydrological models, advantages and weaknesses of radar applications in flood assessment and mapping technology, training on the analysis of the catchment characteristics of a specific river basin and the rainfall-runoff response of the basin to precipitation inputs and flood forecasting are necessary for effective running of the technology.

- To increase cooperation of NMHS of Ukraine with the European Flood Awareness System (EFAS). This will help to overcome the barrier of receiving of satellite, meteorological and hydrological data and lack of flood forecasting personnel. NMHS of Ukraine can use opportunity to sign the license agreement with Delft company to use free some Delft products, especially Delft-FEWS operationally.

- To increase the efficiency of insurance system, these have to be adopted. To do this, following the modernization of the Hydrometeorological Monitoring Service and the implementation of flood risk assessment and mapping technology, a powerful awareness campaign for stakeholders and insurance companies should be conducted to clarify the benefits of using the technology and develop regulatory mechanisms for the use of technology by stakeholders and insurance companies.

Flood insurance is a type of property insurance that covers a dwelling for loss sustained by water damage specifically due to flooding caused by heavy or prolonged rain, melting snow, coastal storm surges, blocked storm drainage systems, or levee dam failure. In many places, flood is considered as a vis major event, and the damage or destruction it causes are uncovered if you do not get supplemental insurance.

In developed countries, for example in the USA, the federal National Flood Insurance Program (NFIP) offers flood insurance to homeowners in participating communities, along with those who are determined to be in the NFIP-designated floodplains, though the policies are offered through private insurers, the government sets the rates.

The pricing of flood insurance policy is based on the NFIP-designated flood zone in which the property is located. Flood hazard zoning is usually based on flood’s risk assessment and mapping technology. This means that the technology of flood risk assessment is not only directly linked to the risk assessment and zoning, but also directly used by the insurance business to evaluate and recover damages.

In Ukraine, the insurance business still does not take advantage of the use of modern technologies for risk assessment. The insurance procedure is optional. The population is not motivated for compulsory insurance, since the state compensates for the flood damage from the state budget. Those flood victims who received compensation from the insurance company are not eligible to receive assistance from the state.

The League of Insurance Organizations of Ukraine proposes to amend the Law of Ukraine "On Insurance" and to introduce a mandatory flood insurance system that will take into account risk zoning, as it is used in the world practice of insurance (Pusch, 2004). Improving the insurance system will facilitate the introduction and dissemination of flood risk assessment and mapping technology in Ukraine.

List of barriers and identified measures to overcome determined barriers on implementation and dissemination of flood’s risk assessment and mapping technology is shown in the table 2.13.

Table 2.13. List of barriers and measures to overcome determined barriers on implementation and dissemination of flood’s risk assessment and mapping technology

Determined barriers	Measures identified to overcome determined barriers	Kind of measure

Lack of state support of hydrometeorological monitoring; measuring equipment, gauges and data transferring and collecting instruments have deficient technology.	Increasing of state support of hydrometeorological monitoring, search for investment, financial credits, funding	Prevention
Lack of long-term satellite, meteorological and hydrological data sets	Strengthen Collaboration with EFAS	Warning
Lack of experts for modelling and forecasting of floods	Education of experts for modelling and forecasting of floods	Warning
High financial costs	Implementation of the WMO service delivery strategy	Prevention
Expensive hardware components of technology	Collaboration with EFAS, Delft company (NL) to access to innovative technologies	Warning
Expensive licenses for software components, detailed topographic maps	Access the financial support from donors and funds	Prevention
Imperfect legislative and regulatory framework for technology implementation	Development of legislative and regulatory framework for technology implementation	Prevention
Lack of awareness of information about benefits of technology	Wide awareness of information about benefits of technology	Prevention
Non-efficiency insurance system: ignorance of the benefits of technology	Increasing of efficiency insurance system	Prevention

Objective tree for flood risk assessment and mapping technology is presented in the Fig. WII-07.

2.5. Linkages of barriers identified in water sector

Ukraine is a country with a difficult and continuous process of economic transition, started after the collapse of USSR and lasting until nowadays. Therefore, there is a set of typical problems or barriers similar to those of any country in transition, additionally aggravated by hostilities in the

East of Ukraine and upcoming corona crisis, started in 2020. Typical barriers of an economy in transition include the long-lasting reform of economic relations and partial privatization, imperfect state support mechanisms that need to be revised on a regular basis, corruption etc. It is impossible to solve these problems within the scope of this project.

The majority of barriers in place for three technologies (Climate-Smart Irrigation, Drought Hazard Assessment and Mapping and Flood Risk Assessment and Mapping) are common. Common barriers could be divided into the following categories:

- economic and financial;
- legislative and regulatory;
- technical;
- informational.

Barriers were analyzed by building problem trees and defining the effects and linkages between the two barriers. Economic and financial barriers are common, because in order to implement new technologies, significant investments are required. In case of Climate-Smart Irrigation technology, agri producers that managed to attract the required investments, are able to see the benefits of technology immediately (let us say within a year), whereas the fruitfulness of money allocation for Drought's Hazard Assessment and Mapping and Flood's Risk Assessment and Mapping strongly depend on the effectiveness of local governments' measures. Common legislative barrier includes the fact that primary and secondary legislation for new promising technologies is missing yet.

There is a wide array of technical problems such as physically missing or fragmented infrastructure for implementation of new technologies, or outdated hydro-metheorogical equipment.

The existing informational barrier in case of Climate-Smart Irrigation technology led to the non-use and damage of existing weather stations in Ukraine, so that they did not benefit agri producers. Informational barrier for Drought's Hazard Assessment and Mapping and Flood Risk Assessment and Mapping are in place due to the limited availability of these technologies even globally (whereas some elements of these technologies are widely available).

Understanding of common barriers may help tackle them in order to promote faster implementation of selected technologies.

2.6. Enabling framework for overcoming the barriers in water sector

There are several legislative documents that directly or indirectly affect irrigation in Ukraine. These documents are the following:

- Water Code of Ukraine (1995) (Water Code, 1995);
- Law of Ukraine "On amelioration of lands" (2000);
- Draft of Strategy of development of agriculture in 2015-2020 (developed in 2015, but not adopted);
- Law of Ukraine "On Environmental Impact Assessment" (2017);
- Strategy of irrigation and dewatering in Ukraine until 2030 (2018) (CMU 2018);
- Governmental Program to reduce the cost of agricultural equipment of domestic production in 2020 (CMU 2020).

Water Code of Ukraine indicates that water for irrigation has to meet special requirements. It also indicates that irrigation of agricultural lands by sewage water (i.e. grey water) is possible (this process should be authorized by the regional state administrations upon agreement with the central executive body, implementing the state policy of sanitary and well-being of population), which is an important adaptation measure.

Law of Ukraine "On amelioration of lands" defines general terms and concepts of irrigation, dewatering etc. It does not include any targets on the spread of irrigation as a technology. It indicates that the Cabinet Ministers of Ukraine sets standards for environmentally safe irrigation, and dewatering in order to ensure the proper ecological and ameliorative state of the land, the proper quality of irrigation water etc. The Law states that financing of expenses for design, construction and operation of amelioration systems, monitoring of irrigated and dewatered lands, inventory of irrigated lands are carried out at the expense of state and local budgets. It also indicates that the use of grey water for irrigation is possible, the necessary permissions should be obtained.

Draft of Strategy of development of agriculture in 2015-2020 included the section on necessity to irrigate the land in the Southern regions of Ukraine, so that cumulative irrigated area reached 1 million ha. The respective investments were supposed to be launched in 2017 with the financial Aid of World Bank (Krasnopolsky 2016). Despite this, Strategy was not adopted, it indicates the necessity of irrigation measures.

Law of Ukraine "On Environmental Impact Assessment" indicate that irrigation practices on the area above 20 ha subject to Environmental Impact Assessment.

The strategy of irrigation and dewatering in Ukraine by 2030 indicates that Ukraine uses only one third of its potential of agricultural production, amongst other reasons, due to insignificant water supply in more than half of its territory. Water supply's regime deteriorates steadily due to climate change. That is why, areas in Steppe, Forest-Steppe and in some areas in Polissya irrigation is crucially required. In 1998-1999, 1.4 million ha were irrigated (Pedak, 2013). In 2017, less than 500 thousand ha were irrigated. Two-side water regulation (irrigation and dewatering) was conducted only on 250 thousand ha, which constitutes less than 20% of available lands that require irrigation and less than 10% of areas that require dewatering, which indicates the deep crisis of ameliorative agriculture.

The renovation of available irrigation equipment (for conventional irrigation) requires investment of USD 3 billion and would allow irrigation on 1.2 million ha additionally. To implement the Strategy, USD 4 billion are needed. Main source of Strategy finance is State budget, so fulfillment of Strategy is in question.

Law of Ukraine "On Amendments to Some Legislative Acts of Ukraine on the Circulation of Agricultural Lands" (2020) introduces the land market in Ukraine since July 2021. According to it, an owner cannot purchase more than 100 ha until 2023 and not more than 10 thousand ha after 2023.

Governmental Program to reduce the cost of agricultural equipment of domestic production in 2020 (2020) envisages the reimbursement of 20% of costs incurred for the purchase of Ukrainian technologies and equipment.

Climate-Smart Irrigation has prospects for being implemented in Ukraine. One should bear in mind that this technology is a large-scale one, requiring big areas, which is achievable in Ukraine. This trend will persist with the development of full-value land market. However, the consolidation of several small-size plots is also possible.

Moreover, there are EU Directive and Ukrainian legislation on flood and drought:

- DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of the 23rd October 2007 on the assessment and management of flood risks;
- Directive No. 2000/60 / EC "On the establishment of the Community framework for activities in the field of water policy "(Water Framework Directive);

- The Decree No. 271-p of the Cabinet of Ministers of Ukraine dated 30th March, 2016 approved the National Action Plan for Combating Land Degradation and Desertification.

These documents can be considered as a general precondition for implementation for the three selected technologies of water sector. Despite the availability of these documents, more specific impediments exist, and they can be reviewed in the tables 2.14-2.16 below.

Table 2.14. Enabling framework for Climate-Smart Irrigation

Enabling framework	Comments
Legislation	The creation of water users' associations (WUAs) in the basin would help to establish consistent property rights in within inter- and intrafarm networks. Developed mechanisms for state support would help to acquire the irrigation machinery and elements of the climate-smart irrigation system by farmers. Transferred intrafarm irrigation networks to the local governments together with available credit funds would promote the use of technology. Slow increase in water tariff by WUAs (until the tariff reaches the size of prime cost) would help to renew main water pipes, that would be of useful to both small and large agri producers. More thorough control of water withdrawal by controlling bodies would prevent from unauthorized water intake.
Financial policy	Long-term credit funding (and soft loans) from international financial donors, allocated through Ukrainian commercial banks would help to overcome the barrier of high cost of capital and partially revitalize Ukrainian banking system. Import tax exemptions and special funding program would help to overcome the problem of high cost of technology.
Technical aspects	Developed complex national target economic program stimulating machinery output would result in the production of domestic equipment for irrigation. The cooperation of machinery producers with IT companies would ensure consistent development of hardware and software for the technology.
Sectoral strategy	The inclusion of Climate-Smart Irrigation technology to the existing Strategy of irrigation and dewatering in Ukraine by 2030 might acknowledge the problem of water insufficiency and the implementation of contemporary technologies.
Awareness raising	The study of international experience, awareness raising campaigns that could be conducted by equipment sellers, as well as training programs for representatives of agri companies would promote the benefits of technology.

Table 2.15. Enabling framework for drought hazard assessment and mapping technology

Enabling framework	Comments
Regulation and legislation	Overcoming this barrier could be facilitated by the adoption of the Law "Sustainable development strategy of Ukraine by 2030", whose project was developed in 2018. This law provides for the creation of systems of balanced production of food and the introduction of

	methods of agriculture that allow to increase the sustainability and productivity and increase production volumes, promote the conservation of ecosystems, strengthen the ability to adapt to climate change, extreme weather events, droughts, drought, flood and gradually improve the quality of land and soil. The Coordination Council on Land Degradation and Desertification should include in the NAP a list of measures for the implementation of drought hazard assessment and mapping technology, its dissemination, exploitation of results and the creation of a regulatory framework to overcome financial and bureaucratic obstacles to its implementation. The implementation of drought's hazard assessment and mapping technology in Ukraine needs to create a legal framework for the implementation of satellite monitoring technologies.
Economic and financial	Increasing of state support of hydrometeorological monitoring, search for investment, financial credits, funding. IBRD experts have established [14] that the modernization of hydrometeorological monitoring of Ukraine requires attracting investments of USD 82 million, which will pay off in 2 years, and after 7 years their efficiency exceeds to 300%. The index of effectiveness of the investments required for the technical modernization and development of the NMHS of Ukraine ranges from 1: 4.1 to 1: 10.8: each dollar that will be invested in monitoring upgrades can benefit from $ 4 to $ 11 at the expense of the warning loss from natural meteorological phenomena. The modernization of monitoring and use of modern technologies for drought hazard assessment and mapping will allow to get considerable economic effect in different sectors of the economy, which depend on the weather. To overcome economic and financial barriers, it can help the implementation through the NMHS of Ukraine of the WMO service delivery strategy. The goal of the Strategy is to help NMHSs raise standards of service delivery in the provision of products and services to users and customers. On the basis of the improved quality of services, we should implement commercial activities that will generate income, additional to the state provided funding. Low level of salary in the monitoring department of SESU: service is not attractive for highly qualified specialists.
Technological	Joining the NMHS of Ukraine to the EUMETNET. Ukraine is the Associate member of EU and can join the organization and gain access to space monitoring information. It will be an effective measure that will help to overcome operational quality and efficiency gaps/ barriers. This will bring the whole work and system to new standards and will broaden access to new resources and collaboration. The implementation of the WMO service delivery strategy will help to overcome technological barriers.
Informational	Wide awareness about benefits of technology. Training programs for representatives of insurance and agri companies would promote the benefits of technology. The creation of new informational channels by using public media and internet.

Table 2.16. Enabling framework for flood's risk assessment and mapping technology

Enabling framework	Comments
Regulation and legislation	For the development of legislative framework for technology, implementation could be facilitated by the adoption of the Law "Sustainable development strategy of Ukraine by 2030", whose project was developed in 2018. For next developing of regulatory framework, there could be the creation of flood's risk management plan (FRMP), and preliminary flood's risks assessment (for 9 River basin districts of Ukraine). The implementation of drought hazard assessment and mapping technology in Ukraine needs to create a legal framework for the implementation of satellite monitoring technologies.
Economic and financial	Increasing the state support of hydrometeorological monitoring, search for investment, financial credits, funding. IBRD experts have established that the modernization of hydrometeorological monitoring of Ukraine requires to attract the investments of USD 82 million, which will pay off in 2 years, and after 7 years their efficiency exceeds to 300%. The modernization of monitoring and use of modern technology's flood risk assessment and mapping will allow to get considerable economic effect in different sectors of the economy, which depend on the weather. To overcome economic and financial barriers, it can help the implementation through the NMHS of Ukraine of the WMO service delivery strategy. The goal of the Strategy is to help NMHSs raise standards of service delivery in the provision of products and services to users and customers. On the basis of improved quality of services, there should be the implementation of commercial activities that will generate income, additional to the state provided funding. Low level of salary in the monitoring's department of SESU: service is not attractive for highly qualified specialists.
Technological	Increased cooperation of NMHS of Ukraine with the European Flood Awareness System (EFAS) and joining to the EUMETNET. This will help to overcome the barrier of receiving of satellite, meteorological and hydrological data and lack of flood forecasting personnel. NMHS of Ukraine can use opportunity to sign the license agreement with Delft company to use free some Delft products, especially Delft-FEWS operationally. The implementation of the WMO service delivery strategy will help to overcome technological barriers, too.
Informational	Prepare and carry out wide awareness campaigns by authorities, the media and NGOs. It is necessary to intensify the campaign to highlight the activities of the hydro-meteorological service, types of forecasting and warning opportunities of the phenomena, the benefits of using early forecast, government, business and the media. The Ministry of Energy and the Environment, the State Emergency Service, together with the Ministry of Information Policy, should launch a public awareness campaign on the use of flood assessment and mapping results to prevent flood. The creation of new informational channels using public media and internet.

Chapter 3 Summary and Conclusions

The three CC adaptation technologies on agriculture were prioritized by stakeholders under the first stage of TNA implementation. In this study, the barriers and possible enabling measures were analyzed in terms to define prospects for further technology implementation and scaling up.

Each technology has a set of particular barriers which mainly caused by their technical specification, target consumer groups, and relevancy to national priority.

Thus, the specific obstacles and prejudices about the introduction of DICA technology are the following: (i) long-term investment risk in the absence of an effective agricultural land market in Ukraine, (ii) lack of competent specialists in farms for large-scale implementation and (iii) relatively high level of investment expenditures with a lack of government support. However, the implementation of this technology is in line with the objectives of the national "Irrigation and drainage strategy in Ukraine by 2030", which seeks the requirement to restore irrigation on the 1.2 million hectares in the areas around reservoirs, major trunk channels with available pumping stations and other interfarm systems by scaling up to the area of 1.7 million ha. It also stimulates the development of irrigation technologies and the production of agricultural equipment, in particular, by providing compensation to farmers for purchasing national production equipment.

In terms of the Agroforestry practice implementation, the next main obstacles were specified: (i) long-term investment risk in the absence of an effective agricultural land market in Ukraine and with lack of government support, (ii) legislative and institutional uncertainties regarding mechanisms for transferring ownership for shelterbelts to the end-user and acquisition of a shelterbelt management right, and (iii) lack of competent specialists in agroforestry for the development of project documentation and appropriate selection of tree species. Moreover, there are no mechanisms for transferring ownership for shelterbelts to the end-user, such as a farm, cooperative or state organization, which leads to the fact that shelterbelts remain without tending and protection. There is a growing interest of farmer in shelterbelt's management, which shapes an offer for the stimulation of the nut tree seedlings and bioenergy crops market. Forest crops are cultivated in the nursery of state forestry enterprises that belong to the forestry system. However, there is a shortage in the supply of planting material that occurs on a regional basis. There is also a lack of methodologies for carrying out shelterbelt's inventory. The average field-protecting forest cover in Ukraine is 1.3-1.5%, and the optimal should be 3-4.5%, depending on the natural and climatic zone. Thus, for reliable protection of cultivated land, the area of field-protecting forest stands should increase by 2-3 times. Thus, in terms of the agroforestry developing, significant state support is required and justified.

In terms of BMF, this technology is mainly used in greenhouse complexes and planting vegetables in the southern regions. However, farmers still prefer plastic counterparts over biofilms, due to the higher purchase price of biofilms. It is often not taken into account that the economic cost of conventional polythene, in addition to the price of the product, also includes the cost of disposal and use.

Thus, the application of mulching with the use of biodegradable films technology is mainly conditioned by two factors:

- The inadequate supply of biomaterials in the market;
- limited demand due to a lack of understanding of the significant benefits of using biofilm.

It is also important to note that the high cost of the material is a temporary phenomenon, until biopolymers are to be produced on a large scale.

During the first phase of the TNA project development in Ukraine, stakeholders identified three priority technologies for the adaptation of the water sector to climate change, particularly:

- Climate-Smart Irrigation technology;
- Drought Risk Assessment and Mapping;

- Flood Risk Assessment and Mapping.

Climate-Smart Irrigation is a technology that allows more reasonable use of water and fertilizers, and thus promotes water saving and prevents from the deterioration of water quality (as lower amount of nutrients reach water bodies).

Due to climate change, Ukraine already needs irrigated areas to have increased (as nowadays irrigation is being conducted on 500 thousand ha only). Winter of 2019-2020 in Ukraine (with lack of snow or other precipitations) has shown that not only the operating irrigation infrastructure is required, but also the availability of water for irrigation may become an issue itself.

The most significant barriers selected by experts include

- high cost of capital;
- difficulties with access to capital;
- obsolete and physically missing infrastructure for conventional irrigational.

Climate-Smart Irrigation is more expensive than conventional irrigation, thus it requires a set of measures that would make it more affordable for farmers. These measures may include soft loans, fiscal preferences for equipment importers, facilitation of domestic equipment output, formation of water users' associations and others. Should these measures be implemented, Climate-Smart Irrigation technology could have a great potential in Ukraine and could contribute fairly to climate change adaptation.

Drought's risk assessment and mapping are a very important technology for Ukraine, because the climate of its territory is under the influence of atmospheric large-scale circulatory systems, which lead to long periods with shortage in precipitation, resulting in droughts. Increased air temperature and uneven distribution of rainfall, which does not provide an effective accumulation of moisture in the soil caused the increased incidence and intensity of drought. Many researchers have noted that since 2000, there has been a tendency to increase the frequency, intensity and prevalence of seasonal drought. Although drought studies are conducted in Ukraine, they are non-systematic in nature, do not have a clear and functional technological basis and do not prevent the risks and loss of drought in the water and agriculture sectors.

The introduction of technology is extremely important in Ukraine, but there is a number of barriers identified by the project experts on the way to its implementation. Among them there are two groups of *very important barriers*:

- Lack of awareness about benefits of technology;
- Inefficient insurance system: ignorance of the benefits of technology;

and important barriers:

- High financial costs
- Lack of long-term satellite, hydrometeorological data sets
- Lack of state support of hydrometeorological monitoring
- Imperfect legislative and regulatory framework for technology implementation
- Lack of experts for modelling and forecasting of floods.

To overcome d identified barriers on the implementation and dissemination of drought's hazard assessment and mapping technology, Ukraine should take the following steps:

- Increase in the state support of hydrometeorological monitoring, search for investment, financial credits, funding;
- The creation of satellite, meteorological and hydrological database;
- Training of experts for drought assessment and mapping;
- Search for financial support from donors and funds;

- Search for technical aid possibilities;
- Wide awareness about benefits of technology;
- Increasing efficiency of insurance system.

Since 2000, more than 280 emergency floods have occurred in Ukraine. Due to climate change, the frequency and severity of floods are increasing. The implementation of the technology for flood risk assessment and mapping is very important for Ukraine. Its implementation can have significant socio-economic benefits, if a number the barriers are to be overcome.

Very important barriers for implementation according to project experts are:

- Lack of awareness about benefits of technology;
- Lack of long-term satellite, meteorological and hydrological data sets;
- Inefficient insurance system: ignorance of the benefits of technology.

Important barriers are:

- Lack of state support of hydrometeorological monitoring; measuring equipment, gauges and data transferring and collecting instruments have deficient technology;
- High financial costs;
- Lack of experts for modelling and forecasting of floods;
- Expensive hardware components of technology.

During the next phase of the Project, the development of technology action plans will be conducted for overcoming barriers for the transfer and diffusion of prioritized technologies of agricultural and water sectors.

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Annex I A Mapping and Problem Trees in agriculture

Figure AI- 01. Market Mapping of Drip irrigation in the combination with conservation agriculture technology

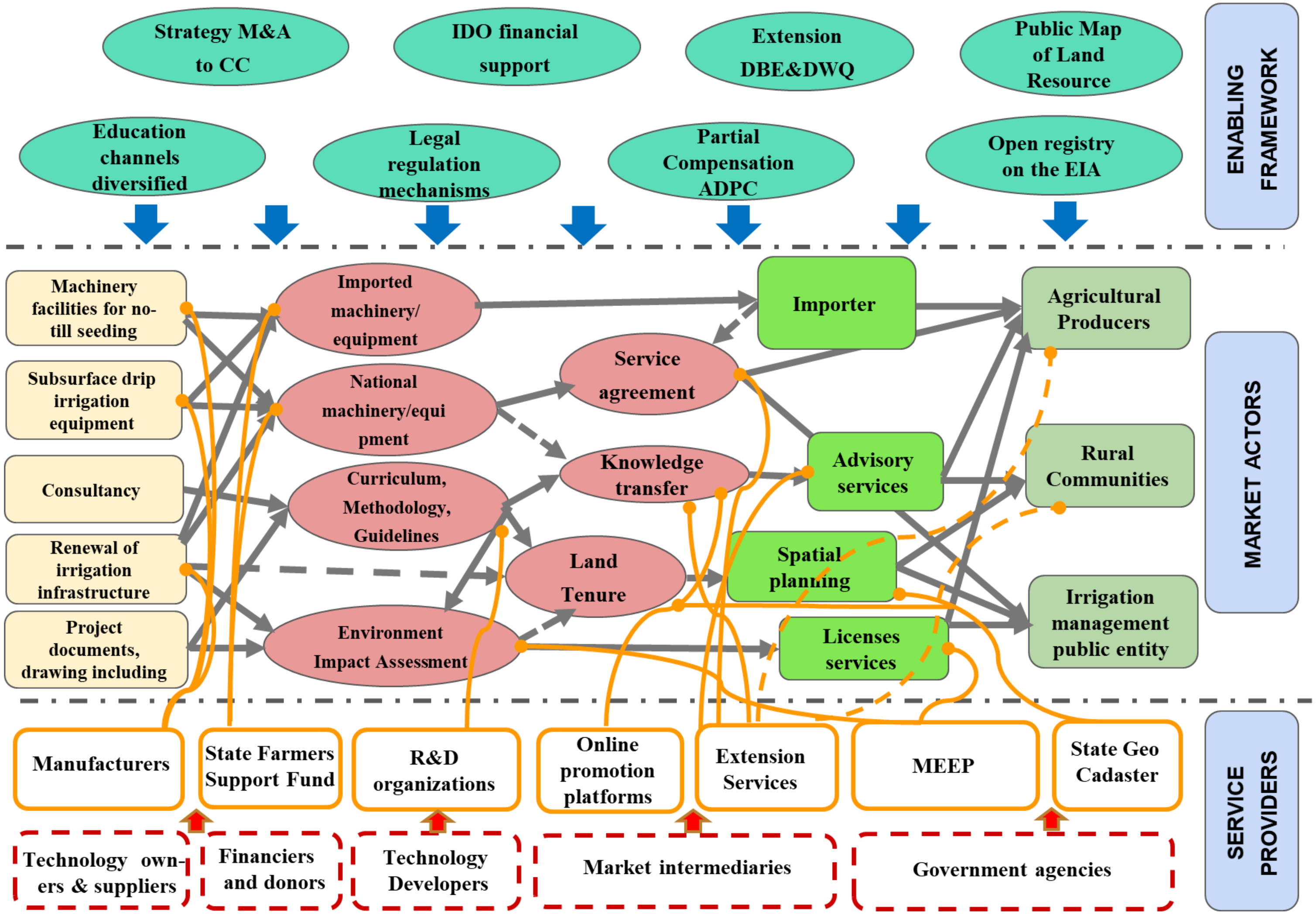


Figure AI-02. Market Mapping of Agroforestry practices (shelterbelt reconstruction)

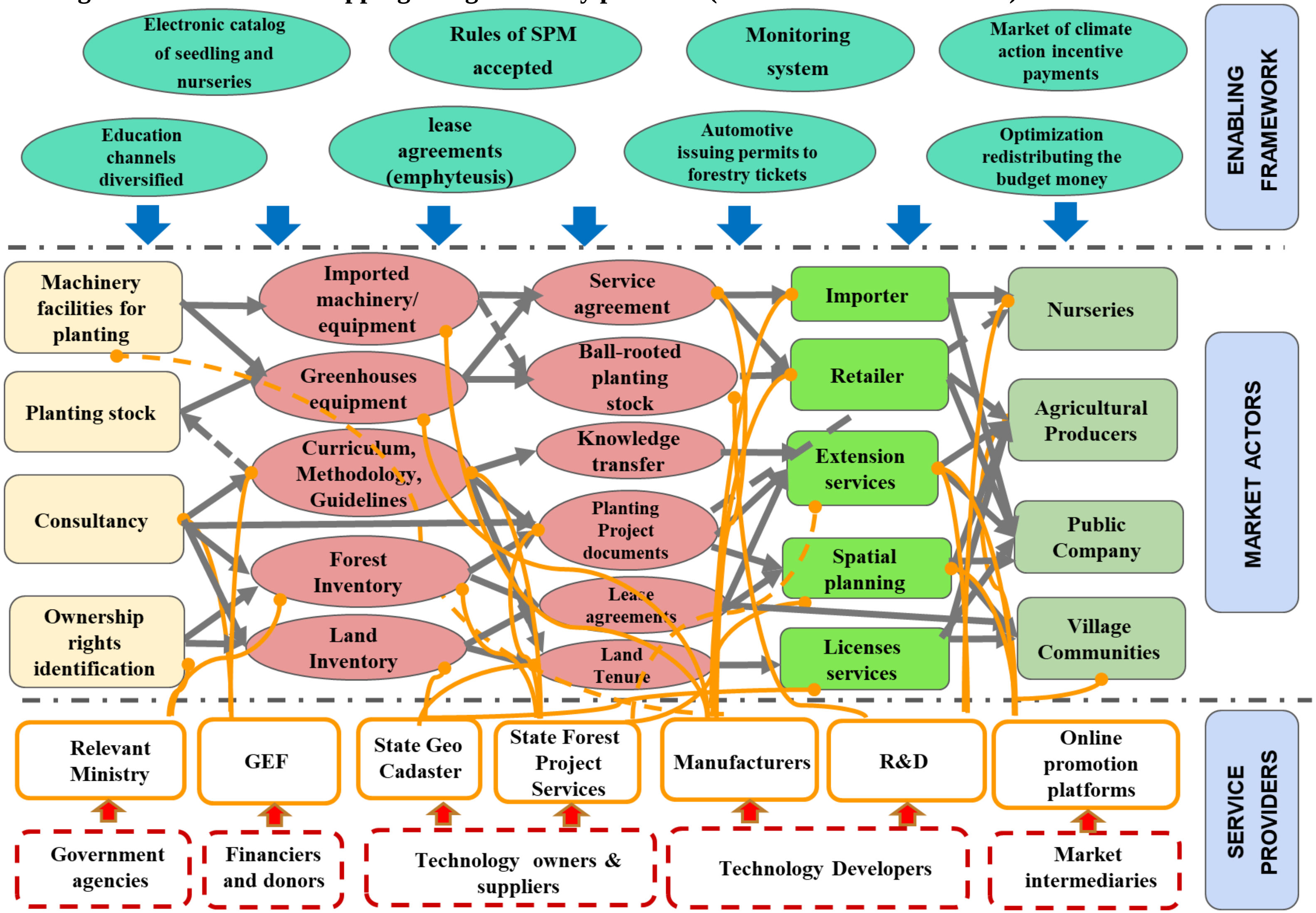


Figure AI- 03. Market Mapping of Integrated Pest and Disease Management (biodegradable mulch film).

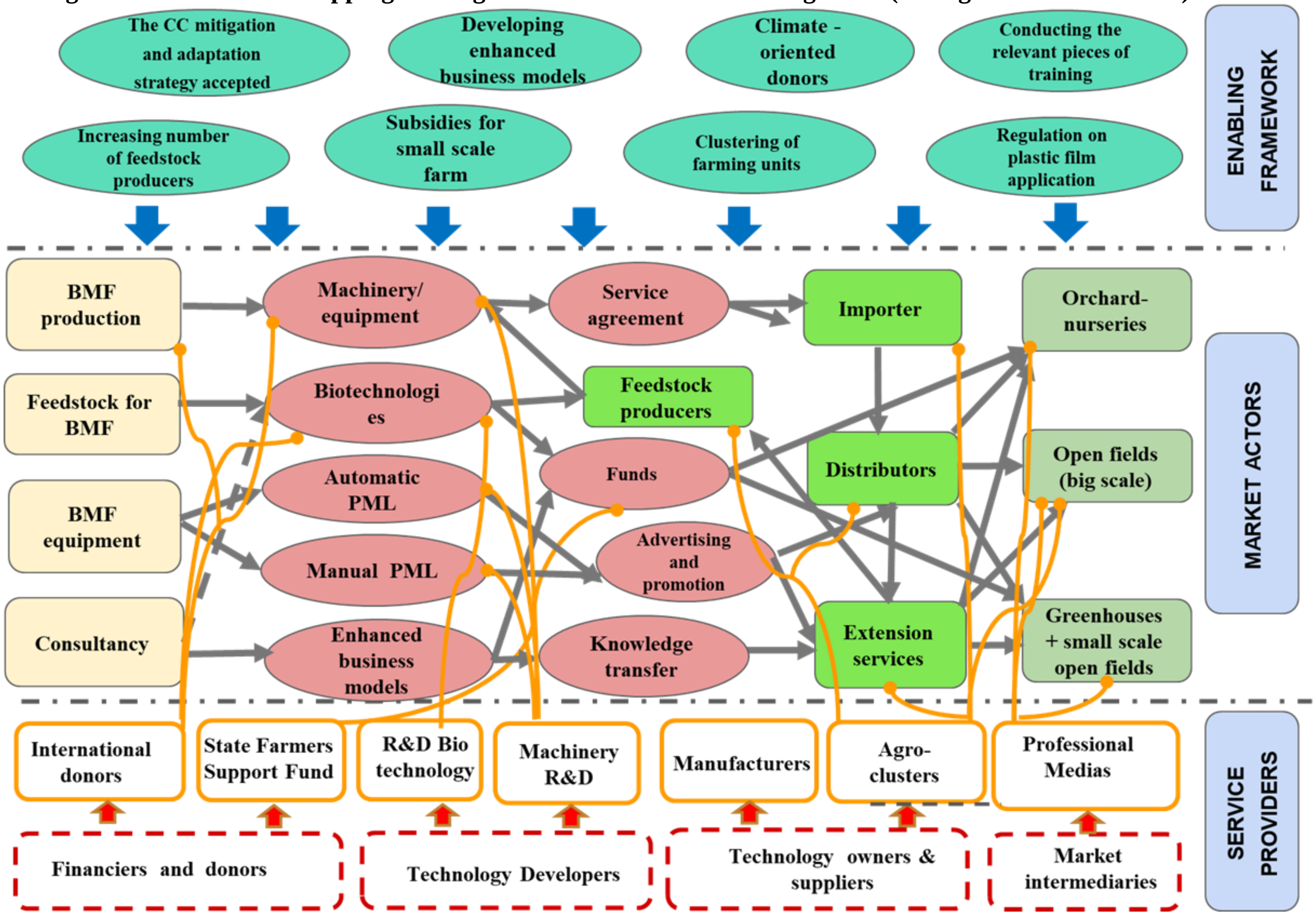


Figure AI- 04. Simplified Problem Tree: Drip irrigation in the combination with conservation agriculture technology

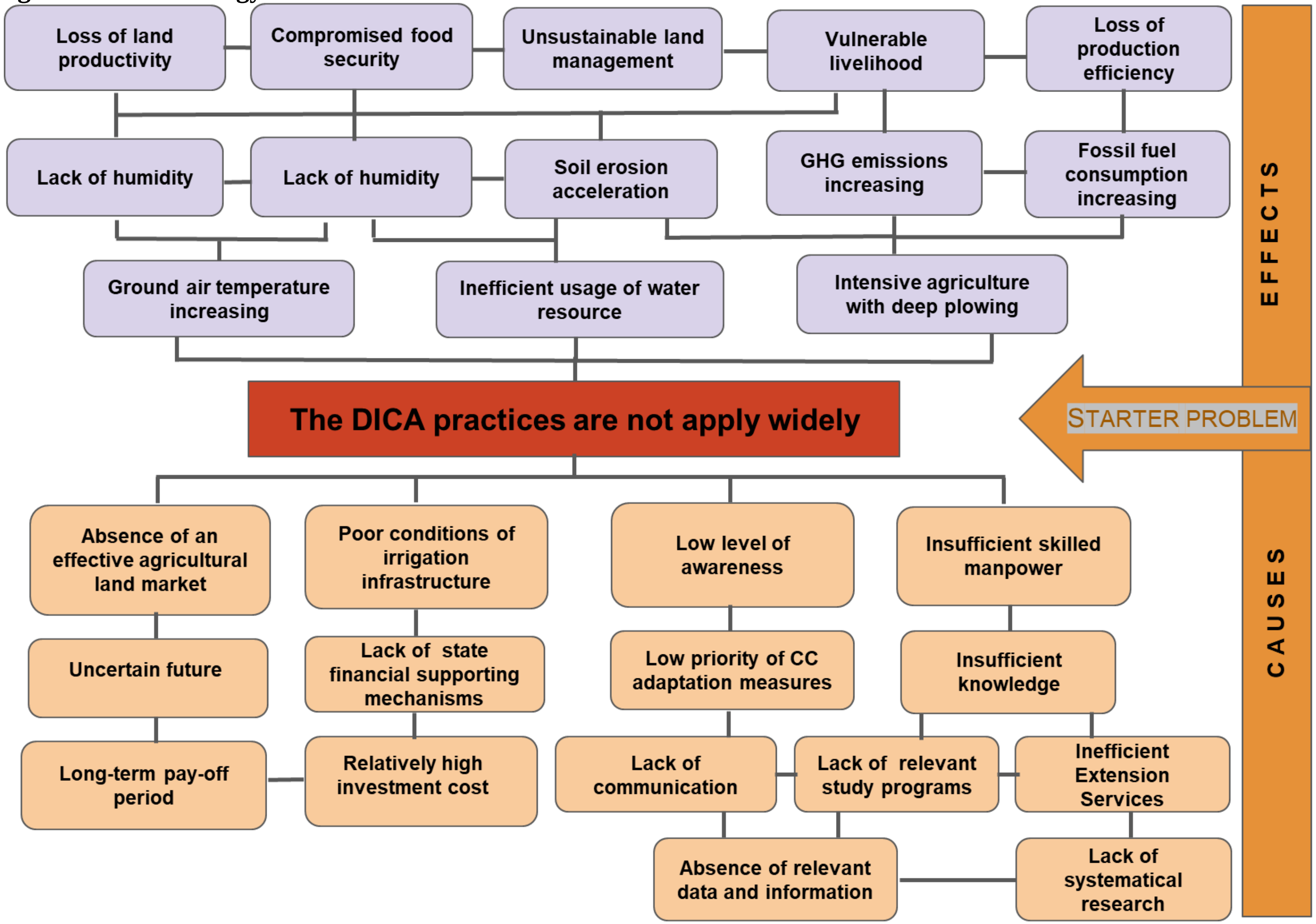


Figure AI- 05. Simplified Problem Tree: Agroforestry practices (shelterbelt reconstruction)

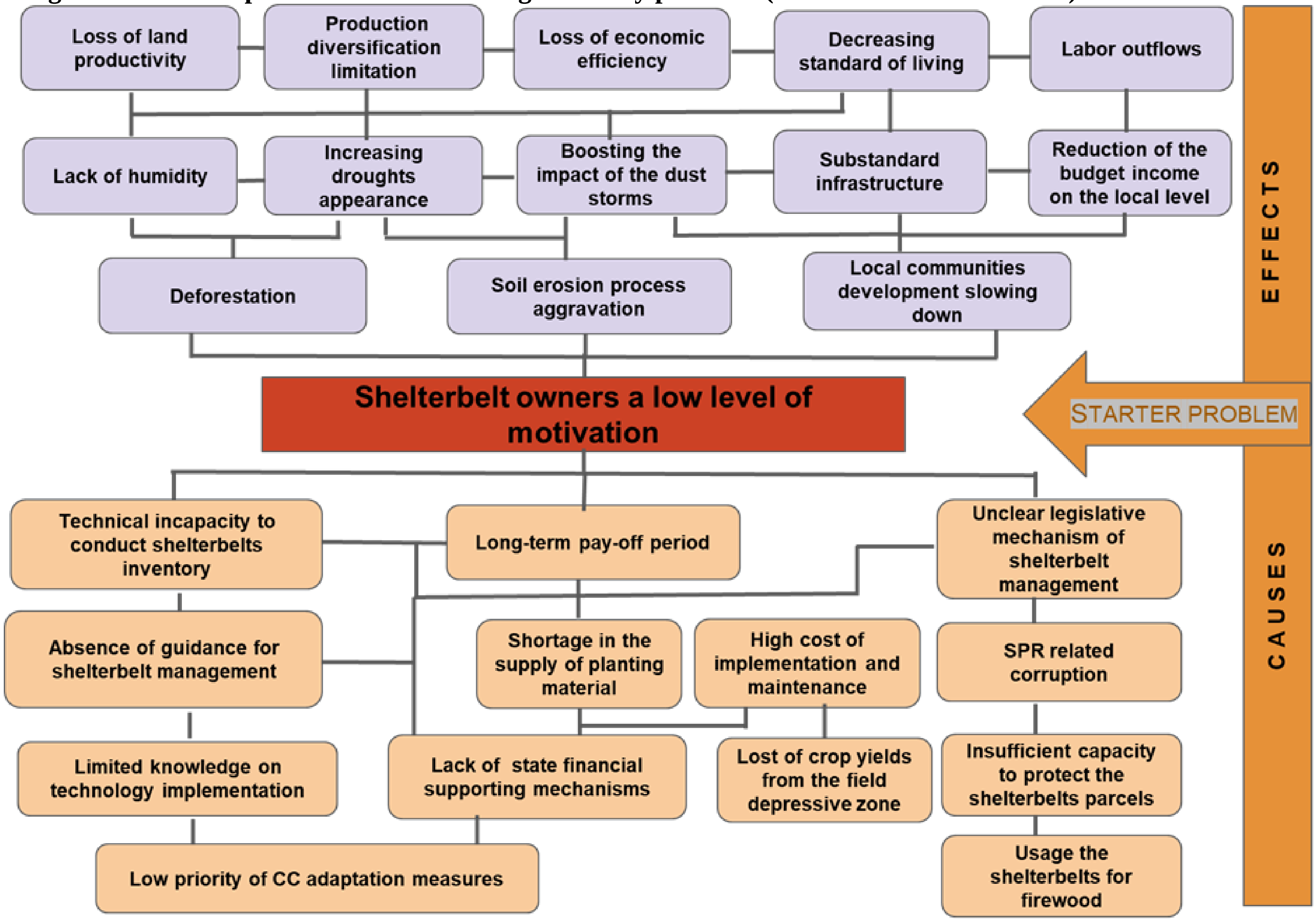
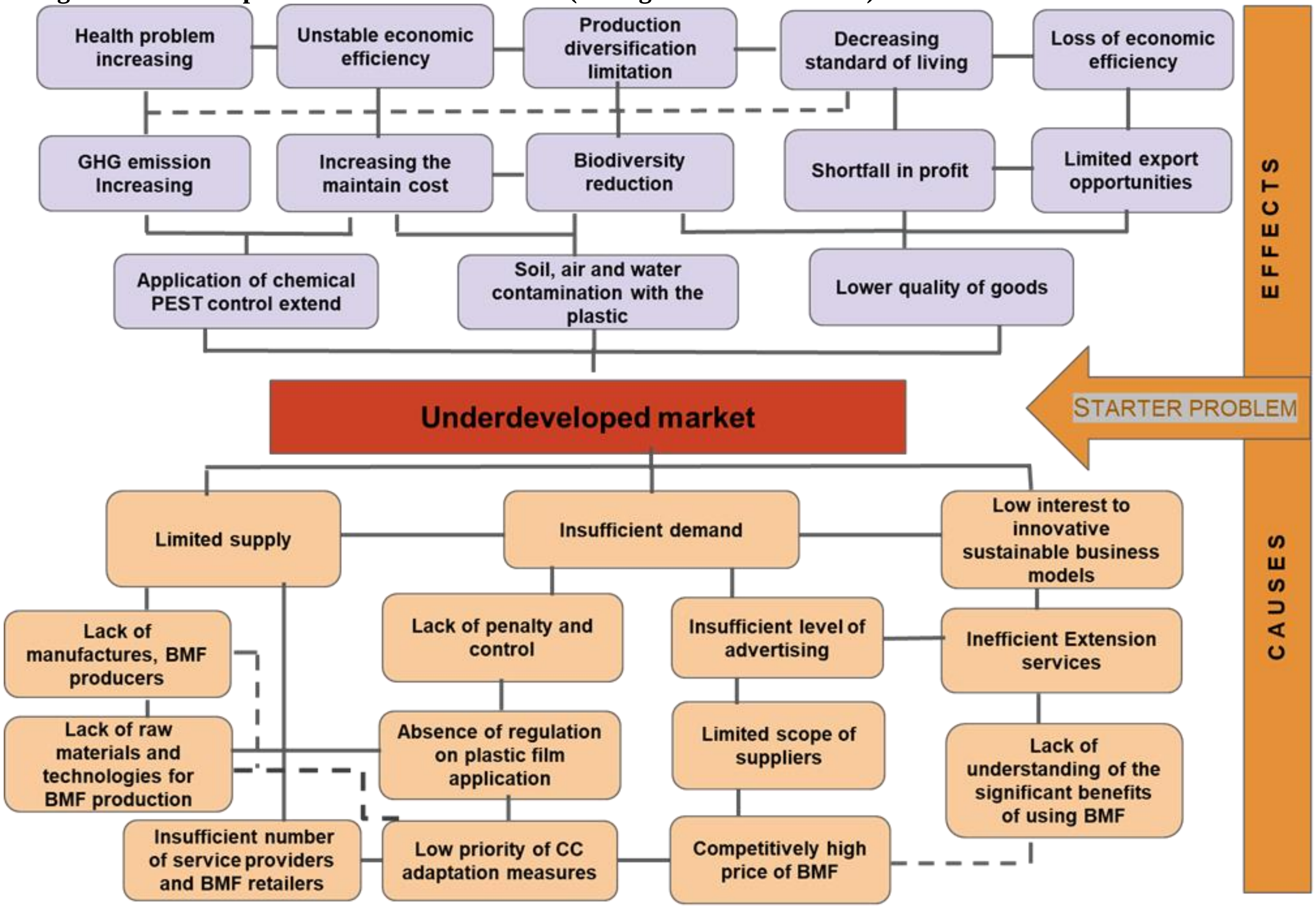


Figure AI- 06. Simplified Problem Tree: IPDM (biodegradable mulch film).



Annex II W. Mapping and Problem Trees in water sector

Figure II W - 01. Problem Tree for Climate-Smart Irrigation Technology

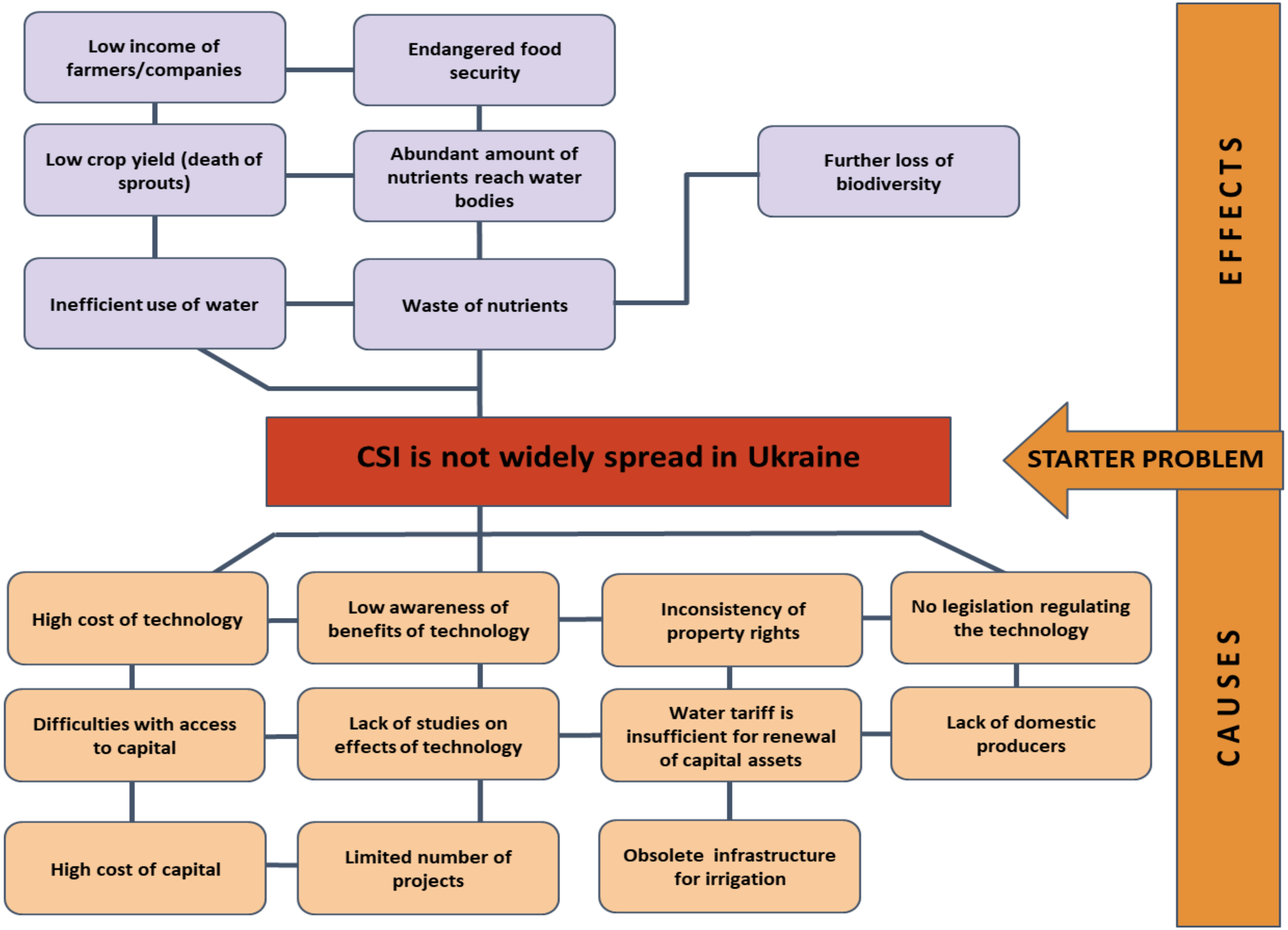


Figure IIW - 02. Objective Tree for Climate-Smart Irrigation Technology

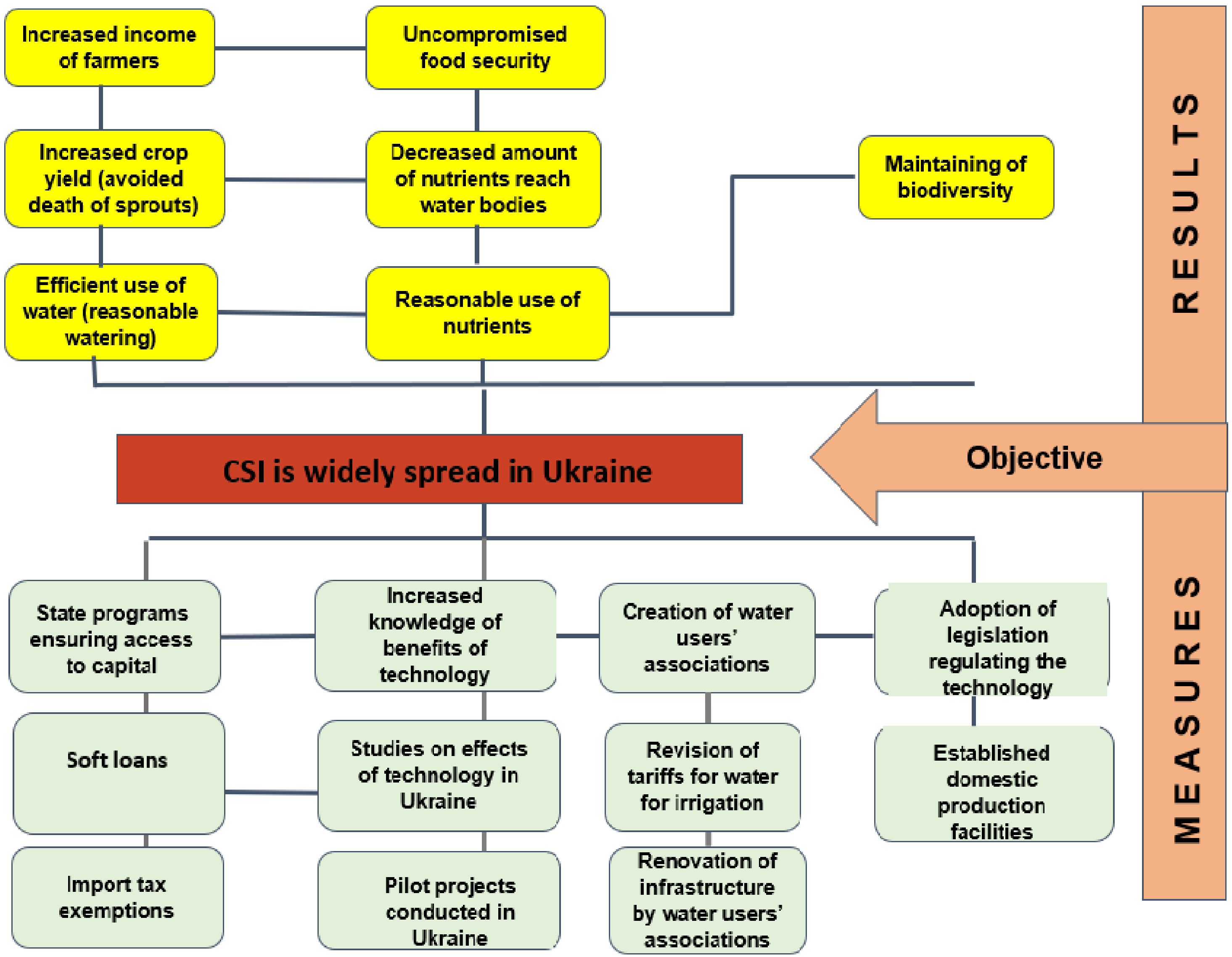


Figure IIW – 03. Market mapping for Climate-Smart Irrigation

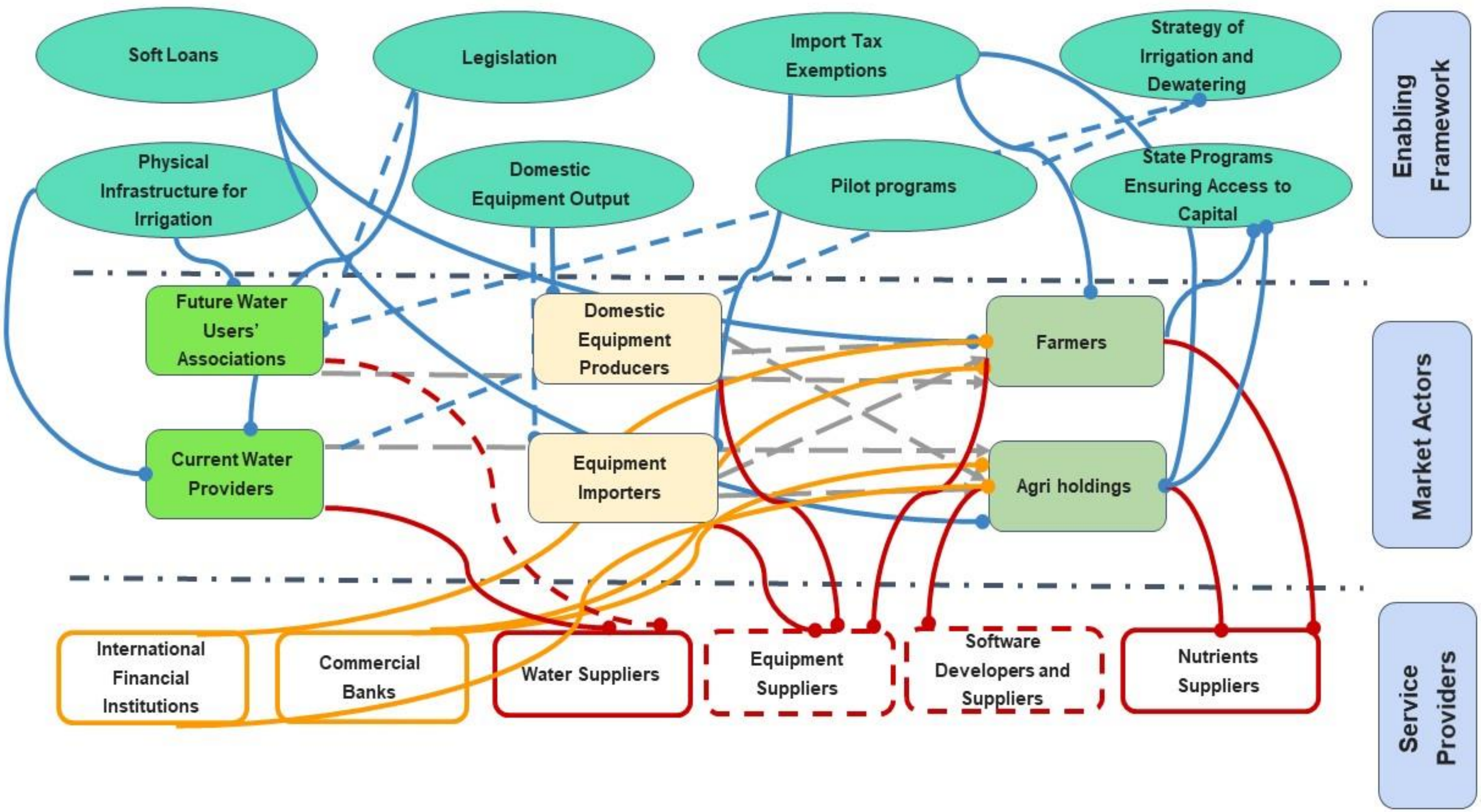


Figure IIW - 04. Problem tree for drought risk assessment and mapping technology

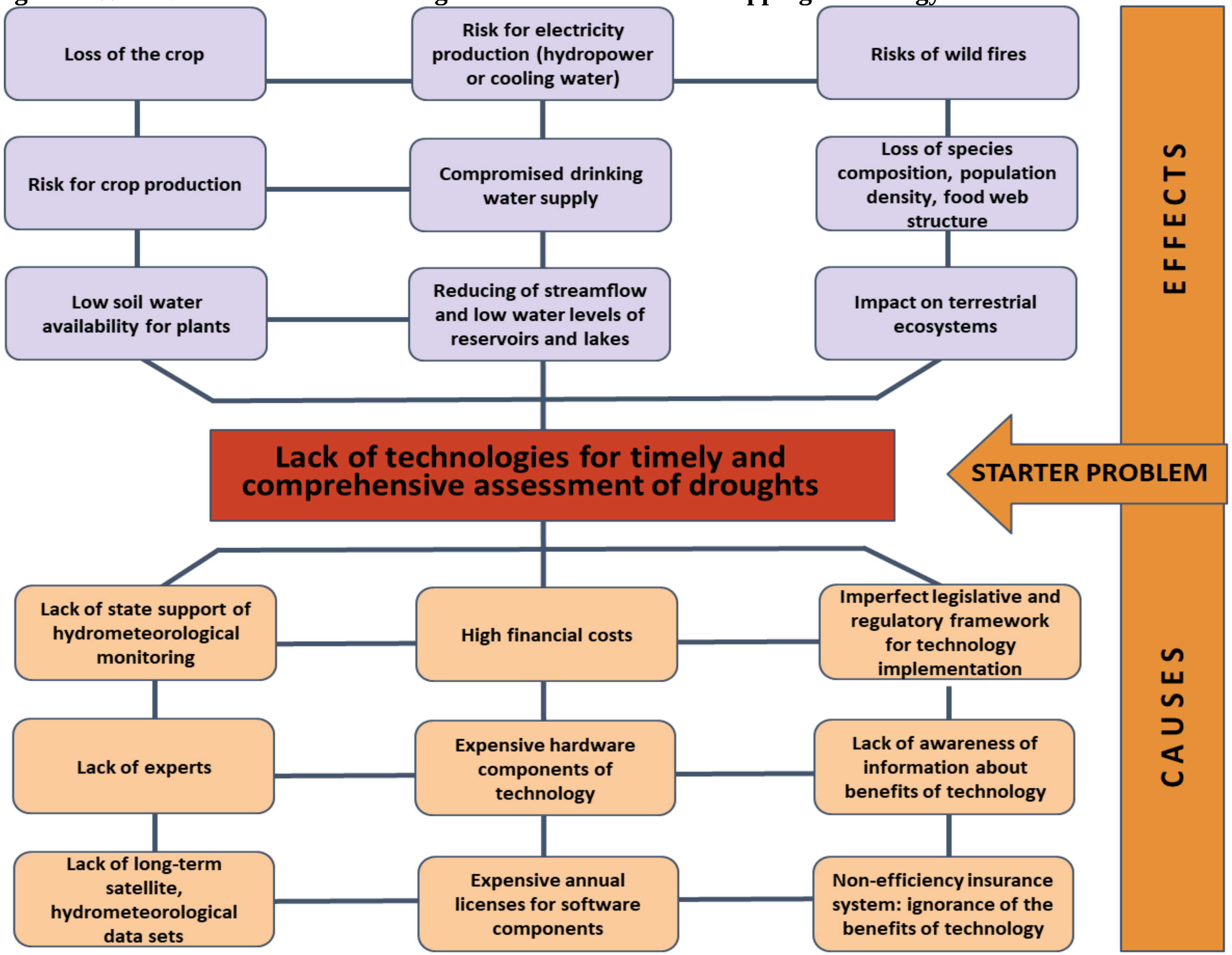


Figure IIW - 05. Objective tree for drought hazard assessment and mapping technology

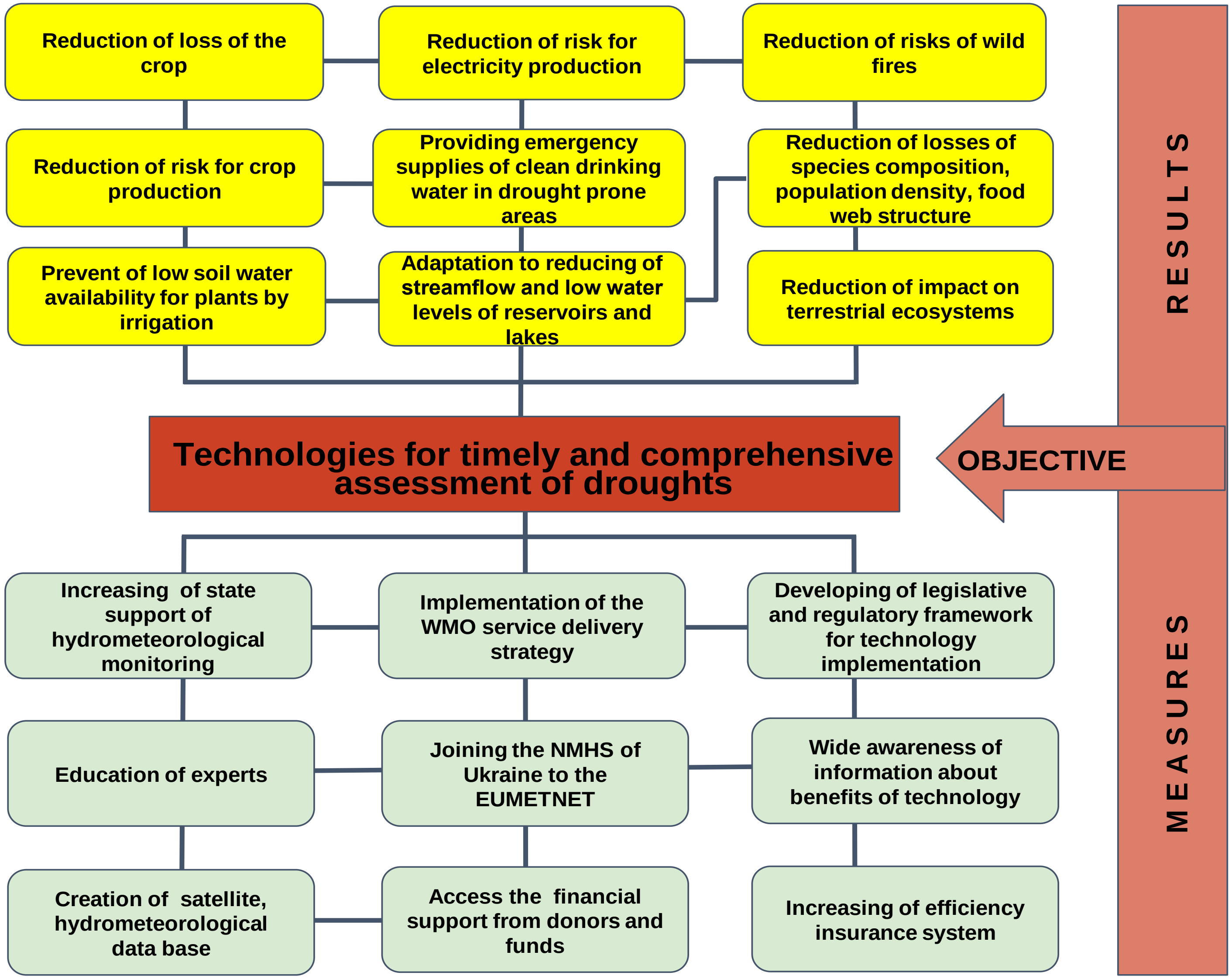


Figure IIW - 06. Simplified Problem Tree for flood risk assessment and mapping technology

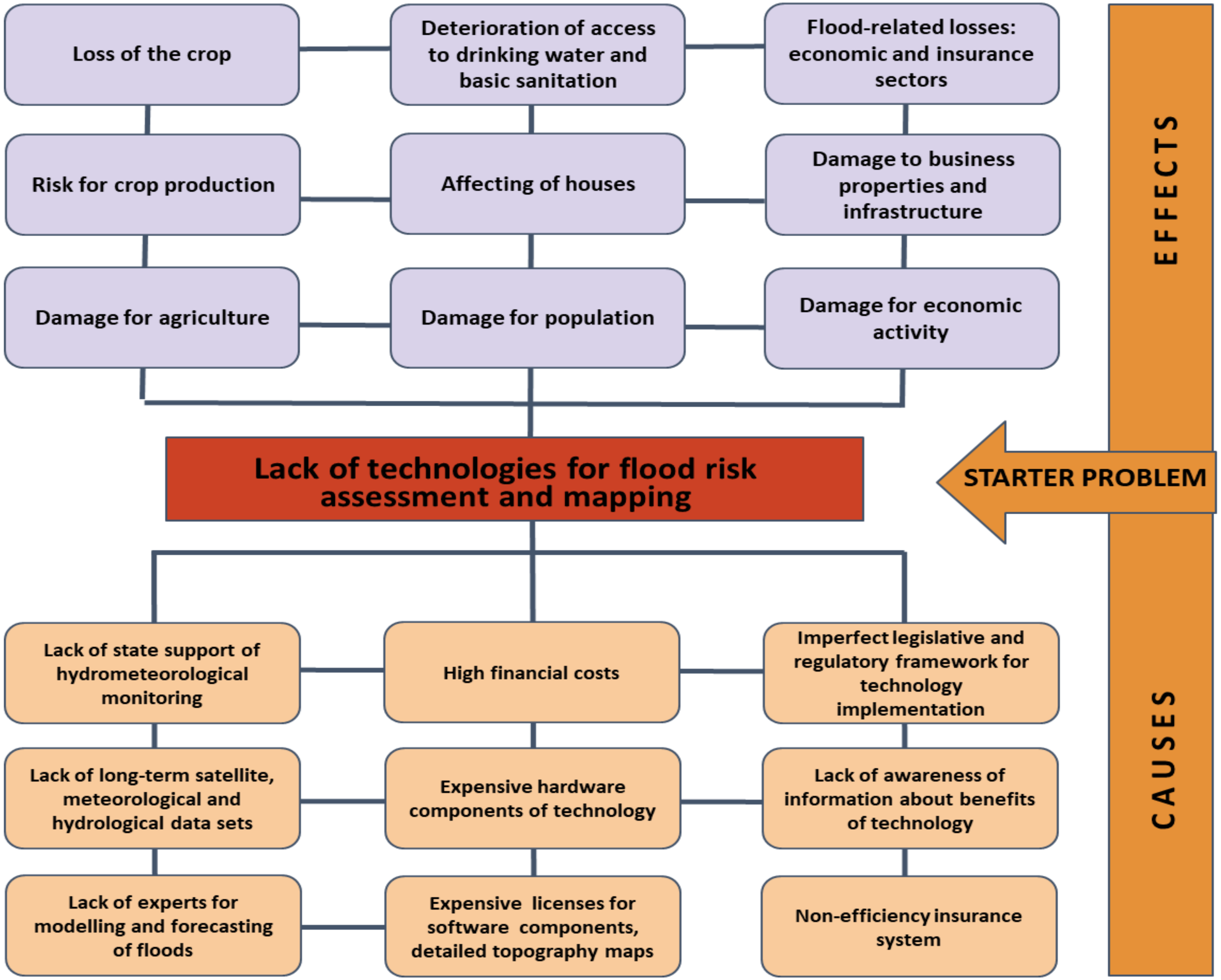
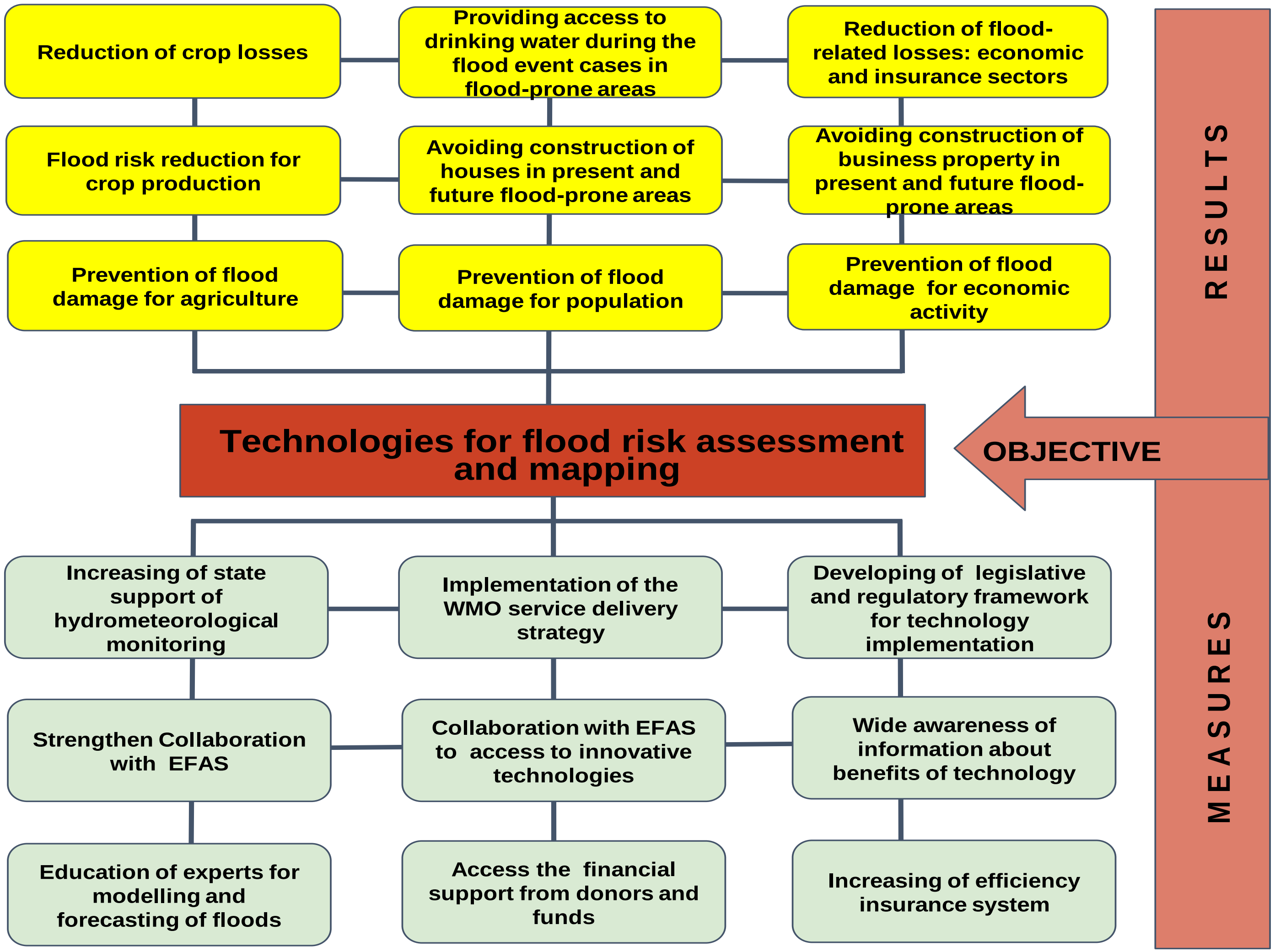


Figure IIW- 07. Objective tree for flood risk assessment and mapping technology



Annex III A List of stakeholders involved and their contacts

Table III A -01 Stakeholders analysis for the Drip irrigation in the combination with conservation agriculture technology

Key Actors Group	Stakeholder Name	Significance
Technology Developers	Crop Care Institute	https://cropcare.institute/
	Institute of Water Problems and Land Reclamation NAAS	http://igim.org.ua
	Ukrainian Scientific and Research Institute for Forecasting and Testing Machinery and Technologies for Agricultural Production named after L. Pogorilogo	http://www.ndipvt.com.ua/
	Institute of Agricultural Microbiology and Agro-Industrial Production	https://ismav.com.ua
	Institute of irigated agriculture	http://izpr.org.ua/
Technology owners and suppliers	PJSC “The plant “Fregat”	https://fregat.mk.ua/en/about-the-company/
	LTD Siva-Agro	https://www.siva-agro.com/en/
	Agro-Soyuz	http://www.agrosoyuz.com/en
	Netafim	http://www.netafim.com.ua/
Product users	LLC Zorya-Yug	https://inspections.gov.ua/subject/view/about?subject_id=3259
	Agro-Myr	https://agrom.com.ua/
	DP DG Veliky Klin	https://inspections.gov.ua/subject/view/about?subject_id=86298
Financiers and donors	State Farmers Support Fund	https://udf.gov.ua/
	Credit Agricole Bank	https://credit-agricole.ua/en/agro-biznesu/
	International Finance Corporation in Ukraine	https://www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/home
	European Bank of Reconstruction and Development	https://www.ebrd.com/ukraine.html
	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH	https://www.giz.de/de/html/index.html
Market intermediaries	No-Till Laboratory	http://ntlab.in.ua/
	Dorada (extention servises)	https://www.dorada.org.ua/doradchi-sluzhbi-ukrajini.html
	Association of Village, Town Councils and United Communities of Ukraine	https://assogu.org.ua/
	Water channels association of Ukraine	https://ukrvodokanal.in.ua/
Information providers	Kurkul	https://kurkul.com/news
	Agro FM	https://www.agro.fm/
	Latifundist Media	https://latifundist.com/
	RBK Ukraine	https://www.rbc.ua/ukr/apk
Government agencies	Ministry of Energy and Environment Protection of Ukraine	https://menr.gov.ua/en/
	State Agency of Water Resorces of Ukraine	https://www.davr.gov.ua/

	Basin water management companies	https://www.davr.gov.ua/basejnovi-upravlinnya-vodnih-resursiv
	State Geo Cadastr (regional departments)	https://land.gov.ua/
	Village Comunites	
	Oblast administration	https://www.president.gov.ua/lustration/lustr-list/lustr-local-adm/lustr-oda
Educational Institutions	National University of Life and Environmental Sciences of Ukraine	https://nubip.edu.ua/
	Bila Tserkva National Agrarian University	https://btsau.edu.ua/
	Kharkiv National Agricalture University	https://knau.kharkov.ua/
	Mykolaiv State Agrarian University	https://www.mnau.edu.ua/
	State Institution "Scientific and Methodological Center for Information and Analytical Support of Higher Educational Institutions Operation "Agroosvita""	http://nmc-vfpo.com/
International organisation	Food and Agriculture Organisation, UN	http://www.fao.org/countryprofiles/index/ru/?iso3=UKR
	German-Ukrainian Agricultural Policy Dialogue	https://apd-ukraine.de/ua/pro-proekt

Table III A – 02. Stakeholders analysis for the Agroforestry practices (shelterbelt reconstruction)

Key Actors Group	Stakeholder Name	Significance
Technology Developers	Ukrainian Research Institute of Forestiy and Forest Melioration	http://uriffm.org.ua
	Institute bioenergy crops and sugar beet of the National Academy of Agrarian Sciences Ukraine	http://bio.gov.ua
	AgroCompany "Kolos"	https://www.agrokolos.com.ua/
	Research Agroforestry Center "Stepoviy"	http://uriffm.org.ua/struktura/naukovo-doslidna-merezha
Technology owners and suppliers	State Geo Cadastr	https://land.gov.ua/
	State Forest Project Services	http://www.lisproekt.gov.ua/
	Ukrainian Nut Association	https://ukr-nuts.org/
	Land surveying services	
	Research Agroforestry Center "Stepoviy"	http://uriffm.org.ua/struktura/naukovo-doslidna-merezha
Product users	AgroCompany "Kolos"	https://www.agrokolos.com.ua/
	Farm Arkadia	
	Institute of Water Problems and Land Reclamation	http://igim.org.ua
	Public Companies	
Financiers and donors	Global Environment Facilites	https://www.thegef.org/
	State Farmers Support Fund	https://udf.gov.ua/
Market intermediaries	Bioenergy Association of Ukraine	http://www.uabio.org/
	Dorada (extention servises)	https://www.dorada.org.ua/doradchi-sluzhbi-ukrajini.html

	Association of Village, Town Councils and United Communities of Ukraine	https://assogu.org.ua/
	NGO "National Association of Agricultural Advisory Services of Ukraine"	
Information providers	Kurkul	https://kurkul.com/news
	Agro FM	https://www.agro.fm/
	Latifundist Media	https://latifundist.com/
	RBK Ukraine	https://www.rbc.ua/ukr/apk
Government agencies	Ministry of Energy and Environment Protection of Ukraine	https://menr.gov.ua/en/
	State Forest Resources Agency of Ukraine	http://dklg.kmu.gov.ua/forest/control/uk/index
	Village Comunites	
	Oblast administration	https://www.president.gov.ua/lustration/lustr-list/lustr-local-adm/lustr-oda
Educational Institutions	National University of Life and Environmental Sciences of Ukraine	https://nubip.edu.ua/
	Bila Tserkva National Agrarian University	https://btsau.edu.ua/
	Kharkiv National Agricalture University named after Dokuchaev	https://knau.kharkov.ua/
	Mykolaiv State Agrarian University	https://www.mnau.edu.ua/
	State Institution "Scientific and Methodological Center for Information and Analytical Support of Higher Educational Institutions Operation "Agroosvita""	http://nmc-vfpo.com/
International organisation	Food and Agriculture Organisation, UN	http://www.fao.org/countryprofiles/index/ru/?iso3=UKR
	Global Environment Facilites	https://www.thegef.org/
	German-Ukrainian Agricultural Policy Dialogue	https://apd-ukraine.de/ua/pro-proekt

Table III A -03. Stakeholders analysis for the Integrated Pest and Disease Management (biodegradable mulch film).

Key Actors Group	Stakeholder Name	Significance
Technology Developers	Mykolaiv State Agrarian University	https://www.mnau.edu.ua/
	Ukrainian Scientific and Research Institute for Forecasting and Testing Machinery and Technologies for Agricultural Production named after L. Pogorilogo	http://www.ndipvt.com.ua/
Technology owners and suppliers	Ginegar	https://ginegar.com/
	IMMER Group	http://www.immer.group/en/
	BASF	https://www.basf.com
Product users	FE "Sadkorn"	
Financiers and donors	USAID	https://www.usaid.gov/
	European Bank for Reconstruction and Development	https://www.ebrd.com/
	State Farmers Support Fund	https://udf.gov.ua/

	UHBDP	https://enviro.uhbdp.org/ua/
Information providers	Agro review	https://agroreview.com
	Responsible future	https://responsiblefuture.com.ua/
	UHBDP	https://enviro.uhbdp.org/ua/
	Association “Ukrainian Agribusiness Club” (UCAB)	http://ucab.ua/
Educational Institutions	National University of Life and Environmental Sciences of Ukraine	https://nubip.edu.ua/
	V.N. Karazin Kharkiv National University	https://www.univer.kharkov.ua/
	Oles Honchar Dnipropetrovsk National University	http://www.dnu.dp.ua/
International organisation	Food and Agriculture Organisation, UN	http://www.fao.org/countryprofiles/index/ru/?iso3=UKR
	German-Ukrainian Agricultural Policy Dialogue	https://apd-ukraine.de/ua/pro-proekt

Table III W -01 List of stakeholders involved in Water sector and their contacts

Name	Affiliation	Position	Comments on Consultations
Romashchenko Mykhailo	The Institute of Water Problems and Land Reclamation	DSc in Technical Science, the Professor, Director of Institute	In person interviews and discussions, electronic mail exchange
Shevchuk Sergii	The Institute of Water Problems and Land Reclamation	PhD in Technical Science, Head of Water Resource Department	In person interviews and discussions, electronic mail exchange
Matyash Tetyana	The Institute of Water Problems and Land Reclamation	PhD in Technical Science, the Department of Information Technology and Innovation Marketing, The Head of Department	The Department of Information Technology and Innovation Marketing
Kussul Nataliia	The Space Research Institute of National Academy of Sciences of Ukraine and State Space Agency of Ukraine	DSc in Computer Science, Professor, the Deputy Director of Institute	In person interviews and discussions, electronic mail exchange
Shelestov Andrii	The National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”	DSc in Information Technologies, Professor	In person interviews and discussions, electronic mail exchange
Boyko Viktoriya	Ukrainian Hydrometeorological Center, Kyiv	PhD in Geography, the Head of Hydrological Forecast Department	In person interviews and discussions, electronic mail exchange

Grebin Vasyl	Taras Shevchenko National University of Kyiv, Kyiv	DSc in Geography, professor, Head of Hydrology and Hydroecology Department	In person interviews and discussions, electronic mail exchange
Kostiantyn Danko	The Ukrainian Hydrometeorological Institute of the State Emergency Service of Ukraine and of the National Academy of Science of Ukraine	PhD in Hydrology, The Head of Laboratory of Flood Risk Assessment and Management	In person interviews and discussions, electronic mail exchange
Didovets Yulii	Potsdam Institute for Climate Impact Research	PhD in Hydrology, Researcher	In person interviews and discussions, electronic mail exchange
Ovcharuk Valeriya	Odesa State Ecological University, Odesa	DSc in Geography, the Professor, Director of Hydrometeorological Institute	In person interviews and discussions, electronic mail exchange
Yuschenko Yuriy	Yuriy Fedkovych Chernivtsi National University, Chernivtsi	DSc in Geography, the Professor, Head of Hydrometeorology and Water Resources Department	In person interviews and discussions, electronic mail exchange
Shevchenko Olga	Taras Shevchenko National University of Kyiv, Kyiv	DSc in Geography, Associate Professor	In person interviews and discussions, electronic mail exchange
Manivchuk Vasyl	Transcarpathian Regional Center of Hydrometeorology, Ushgorod	MSc in Hydrology, Head	In person interviews and discussions, electronic mail exchange
Semenova Inna		DSc in Geography, Professor	
Gopchak Igor	The National University of Water and Nature Management, Rivne	PhD in Geography, Associate Professor	In person interviews and discussions, electronic mail exchange
Grychulevych Liliya	The Basin Department of Water Resources of the Black Sea and the Lower Danube State Water Agency of Ukraine, Odesa	MSc in ecology, MSc in State Administration, The Director of the Basin Department	In person interviews and discussions, electronic mail exchange
Sherstyuk Nataliya	Oles Honchar Dnipro National University, Dnipro	DSc in Geography, the Professor, Dean of Faculty of Geology and Geography	In person interviews and discussions, electronic mail exchange

Annex IV A. Cost-benefit analysis of technologies, agriculture sector

Figure IV A -01. Cost of construction under drip irrigation system[21]

Local cost estimation for construction № 2-1-1

Irrigation system for experimental plot on the area of 18,0 ha construction
Irrigation system for experimental plot on the area of 18,0 ha

Base:	Estimated costs	775,618	thousand UAH.
drawings (specifications) №	Estimated labor inputs	1,38974	thousand man hour
	Estimated labor cost	45,856	thousand UAH
	Average rank of works	3,8	rank

Current prices are taken as of May 31, 2019.

№	Substantiation (code of norm)	Name of works and costs	Unit	Number	Unit cost, UAH: Total / salary	Unit cost, UAH: operation of machines / including salary	Total cost, UAH: Total	Total cost, UAH: salary	Total cost, UAH: operation of machines / including salary	Labor input, man hour: do not involved in machines operation / involved in machines operation, per unit	Labor input, man hour: total
1	2	3	4	5	6	7	8	9	10	11	12
		Chapter 1. Distributive pipelines									
1	*EH22-11-5 for H1=0,1*	*Lay down of flexible pipelines LFT with diameter 160 mm along with hydraulic pressure test*	*1000 m*	*0,8*	*1213,18* *1186,00*	*27,18* *6,31*	*971*	*949*	*22* *5*	*39,52* *0,2008*	*31,62* *0,16*
2	C113-1400 option 1	Flexible pipes LFT for cold water supply, external diameter 150 mm (6"), pressure 0,6 MPa	m	800	180,83 -	- -	144664	-	- -	- -	- -
3	*EH22-11-3 for. H1=0,1*	*Lay down of flexible pipelines LFT with diameter 100 mmм along with hydraulic pressure test*	*1000м*	*1,4*	*951,73* *942,37*	*9,36* *2,17*	*1332*	*1319*	*13* *3*	*31,04* *0,0692*	*43,46* *0,1*
4	C113-1397 option 1	Flexible pipes LFT for cold water supply, external diameter 103 mm (4"), pressure 0,4 MPa	m	1400	80,00 -	- -	112000	-	- -	- -	- -
5	*EH22-11-1 for H1=0,1*	*Lay down of flexible pipelines LFT with diameter 50 mm along with hydraulic pressure test*	*1000m*	*0,7*	*729,41* *727,43*	*1,98* *0,46*	*511*	*509*	*2* *-*	*23,96* *0,0146*	*16,77* *0,01*

[21] Example developed under the project implemented by FAO UA in cooperation with the Institute of Water Problem and Land Reclamation under the GEF project in 2018-2020 (FAO GEF 2019)

1	2	3	4	5	6	7	8	9	10	11	12
6	C113-1393 option 1	Flexible pipes LFT for cold water supply, external diameter 51 mm (2"), pressure 0,4 MPa	m	700	45,83 -	- -	32081	-	- -	- -	- -
		Total expenditures for chapter 1					291559	2777	37 8		91,85 0,27
		Total construction works, UAH					291559				
		including:									
		cost of materials, products and constructions, UAH					288745				
		total salary, UAH.					2785				
		Total expenditures, UAH					1375				
		labor input in total expenditures, man hour					8,66				
		salary in total expenditures, UAH					422				
		Total construction works, UAH					**292934**				
		Total for chapter 1					**292934**				
		Chapter 2. Irrigation pipelines									
7	*EH22-11-1 for 2 man hour - 1000 m*	*Lay down of irrigation polyethylene pipelines with diameter 16 mm on soil surface manually*	*1000m*	*84*	*80,52* *60,72*	*19,80* *4,60*	*6764*	*5100*	*1664* *386*	*2* *0,1463*	*168* *12,29*
8	C113-1372-1A option 3	Polyethylene irrigation pipelines (8 mil, 0,25 m, 0,9 l/hour)	m	84000	1,19 -	- -	100212	-	- -	- -	- -
9	*E47-115-1 for 0,5 machine hour - 1 km*	*Laying (underground) of irrigation pipelines by mechanized way*	*km*	*85,5*	*275,87* -	*275,87* *29,30*	*23587*	-	*23587* *2505*	- *0,725*	- *61,99*
10	C113-1372-1A option 4	Polyethylene irrigation pipelines (10 mil, 0,5 m, 0,9 l/hour)	m	28500	1,38 -	- -	39188	-	- -	- -	- -
11	C113-1372-1A option 5	Polyethylene irrigation pipelines (10 mil, 0,5 m, 1,2 l/hour)	m	28500	1,38 -	- -	39188	-	- -	- -	- -
12	C113-1372-1A option 6	Polyethylene irrigation pipelines (10 mil, 0,5 m, 1,6 l/hour)	m	28500	1,38 -	- -	39188	-	- -	- -	- -
		Total direct costs for chapter 2					248127	5100	25251 2891		168 74,28

1	2	3	4	5	6	7	8	9	10	11	12
		Total for construction works, UAH					248127				
		including:									
		cost of materials, products and constructions, UAH					217776				
		total salary, UAH					7991				
		Total expenditures, UAH					3745				
		labor input in total expenditures, man hour					22,4				
		salary in total expenditures, UAH					1092				
		Total construction works, UAH					**251872**				
		Total for chapter 2					**251872**				
		Chapter 3. Station for boosting, filtering, fertigation									
13	*E18-21-7*	*Water treatment filters installation, diameter 100 mm*	*10pcs*	*0,1*	*1490,20* *811,52*	*678,68* *157,66*	*149*	*81*	*68* *16*	*26,73* *5,0141*	*2,67* *0,5*
14	C1630-109 option 1	Disk filters with flange for water treatment, diameter 100 mm	pcs	1	22447,50 -	- -	22448	-	- -	- -	- -
15	*E16-26-4*	*Meters (watermeters) installation, diameter up to 100 mm*	*pcs*	*1*	*135,81* *99,81*	*36,00* *8,36*	*136*	*100*	*36* *8*	*3,25* *0,266*	*3,25* *0,27*
16	C1630-1823 option 1	Meters (watermeters) for cold water with flange, diameter 100 mm	pcs	1	6631,67 -	- -	6632	-	- -	- -	- -
17	C1630-949 option 3	Steel stands for filter, meter	pcs	3	1250,00 -	- -	3750	-	- -	- -	- -
18	C130-969 option 2	Steel nozzles with flange, diameter 100 mm	pcs	1	793,33 -	- -	793	-	- -	- -	- -
19	*EH22-35-3*	*Valves installation, diameter 100mmм*	*pcs*	*3*	*73,80* *64,80*	*9,00* *2,09*	*221*	*194*	*27* *6*	*2,24* *0,0665*	*6,72* *0,2*
20	C1630-1392 option 1	Valve of Butterfly, diameter 100 mm	pcs	3	2041,67 -	- -	6125	-	- -	- -	- -
21	*EH22-36-1*	*Steel taps and injectors installation, diameter up to 50 mm*	*pcs*	*4*	*60,32* *51,32*	*9,00* *2,09*	*241*	*205*	*36* *8*	*1,71* *0,0665*	*6,84* *0,27*
22	C1630-671 option 1	Ball valves with sleeves for water, diameter 25 mm (external threadxinternal thread)	pcs	3	156,67 -	- -	470	-	- -	- -	- -
23	C1630-671 option 2	Injectors for input fertilizers dissolved in water, diameter 25 mm	pcs	1	1534,17 -	- -	1534	-	- -	- -	- -

1	2	3	4	5	6	7	8	9	10	11	12
69	C113-1285 option 2	Sleeves LFT 2" x LFT 2"	pcs	31	82,50 -	- -	2558	-	- -	- -	- -
70	& C1110-196-31 option 1	Clamp 110x1/2"	pcs	10	91,67 -	- -	917	-	- -	- -	- -
71	& C1110-196-31 option 3	Clamp 110x1"	pcs	10	91,67 -	- -	917	-	- -	- -	- -
72	& C1110-196-31 option 2	Clamp 110x2"	pcs	1	93,33 -	- -	93	-	- -	- -	- -
73	*EH22-34-1 cmoc. 0,5 man hour - 10 pcs*	*Installation of polyethylene joints for irrigation: sleeves, start connectors*	*10 pcs*	*320*	*15,96* *15,96*	- -	*5107*	*5107*	- -	*0,5* -	*160* -
74	C113-1278 option 1	Joining sleeve 16x16 mm	pcs	1200	4,67 -	- -	5604	-	- -	- -	- -
75	C113-1278 option 2	Start connectors LFTxPT	pcs	2000	6,18 -	- -	12360	-	- -	- -	- -
76	C111-1399 option 2	Pickers covered with zinc, diameter of theard is 14 mm, length 1000 mm	ton	0,00935	84670,23 -	- -	792	-	- -	- -	- -
77	C111-124 option 3	Hexagon screws, diameter of thread 14 mm	ton	0,005	75000,00 -	- -	375	-	- -	- -	- -
78	C111-1870 option 4	Washers M14	ton	0,0025	70833,33 -	- -	177	-	- -	- -	- -
79	C1545-549 option 1	Clamp Dy 149x161 mm	pcs	50	35,00 -	- -	1750	-	- -	- -	- -
80	C1545-549 option 2	Clamp Dy 98x103 mm	pcs	150	27,50 -	- -	4125	-	- -	- -	- -
81	C1545-549 option 3	Clamp Dy 52x55 mm	pcs	50	14,17 -	- -	709	-	- -	- -	- -
82	C1541-67-2 option 2	Rubber gaskets, diameter 100 mm	1000pcs	0,01	25000,00 -	- -	250	-	- -	- -	- -
		Total direct costs for chapter 4					149282	19835	24081 5443		626,94 180,69
		Total for construction works, UAH					149282				
		including:									
		cost of materials, products and constructions, UAH.					105366				
		total salary, UAH					25278				
		Total expenditures, UAH					12246				
		labor input in total expenditures, man hour					75,93				
		salary in total expenditures, UAH					3700				

1	2	3	4	5	6	7	8	9	10	11	12
		Total construction works, UAH.					**161528**				
		– –									
		Total for chapter 4					**161528**				
		Total direct cost estimation					756310	30674	53950 9378		981,05 289,62
		Total for construction works, UAH					756310				
		including:									
		cost of materials, products and constructions, UAH.					671686				
		total salary, UAH					40052				
		Total expenditures, UAH					19308				
		labor input in total expenditures, man hour					119,07				
		salary in total expenditures, UAH					5804				
		Total construction works, UAH					**775618**				
		– –									
		Total cost estimation					**775618**				
		Total labor input, man hour					**1389,74**				
		total salary, UAH					**45856**				

Table IV A -01. Cost of shelterbelt construction, two year cycle

No.	Name of works and costs	Unit	Number	Cost per unit (UAH)		Total cost (UAH)			Labour costs for workers not employed in machine maintenance (man-hours) Employed in machine maintenance	
				Total Labour costs	Machinery operations Including labour costs	Total	Labour costs	Machinery operations Including labour costs	Per unit	Total
1	2	3	4	5	6	7	8	9	10	11
1	**1st year**		-	-	-	-	-	-	-	-
2	Deep-plowing in medium soils at a depth of 40–45 cm	ha	0.83	2,314.78 -	2,314.78 573.20	1,921	-	1,921 476	- 9.7259	- 8.07
3	**2nd year**		-	-	-	-	-	-	-	-
4	Single-cut disk harrowing	ha	0.83	70.17 -	70.17 18.53	58	-	58 15	- 0.3144	- 0.26
5	Preplanting cultivation of soil with simultaneous harrowing	ha	0.83	242.66 -	242.66 64.08	201	-	201 53	- 1.0873	- 0.90
6	Short-term heeling-in and preparation of seedlings for planting (taking into account 20% of overplanting)	10,000 stems	0.3331	574.94 574.94	- -	192	192	- -	13.5600 -	4.52 -
7	Planting of seedlings by one tree-planting machine	km	2.776	392.31 111.74	280.57 76.18	1,089	310	779 211	2.4000 1.3128	6.66 3.64
8	Material – 1-2-year-old seedlings:		-	-	-	-	-	-	-	-
9	*Quercus robur* (*Gleditsia triacanthos*)	1,000 stems	1.666	21,000.0		34,986				
10	*Acer campestre* (*Celtis occidentalis*)	1,000 stems	0.555	922.32		512				
11	*Cotinus coggygria*	1,000 stems	0.555	718.32		399				
12	Additional hand planting of seedlings in medium soils in the second year after planting – 20%	1,000 stems	0.555	939.21 939.21	- -	521	521	- -	20.3600 -	11.30 -
13	Material – 1-2-year-old seedlings:		-	-	-	-	-	-	-	-

No.	Name of works and costs	Unit	Number	Cost per unit (UAH)		Total cost (UAH)			Labour costs for workers not employed in machine maintenance (man-hours) / Employed in machine maintenance	
				Total / Labour costs	Machinery operations / Including labour costs	Total	Labour costs	Machinery operations / Including labour costs	Per unit	Total
1	2	3	4	5	6	7	8	9	10	11
14	*Quercus robur* (*Gleditsia triacanthos*)	1,000 stems	0.333	21,000.0		6,993				
15	*Acer campestre* (*Celtis occidentalis*)	1,000 stems	0.111	922.32		102				
16	*Cotinus coggygria*	1,000 stems	0.111	718.32		80				
17	12-time cultivation (4-3-2-2-1) of soil between the rows and in edges, for the five years	km	50.0	111.10 / -	111.10 / 29.34	5,555	-	5,555 / 1,467	- / 0.4978	- / 24.89
18	7-time cultivation (4-3) within the rows in the first two years	km	19.43	96.48 / -	96.48 / 25.48	1,875	-	1,875 / 495	- / 0.4323	- / 8.40
19	3-time (0-0-2-1) loosening of soil around seedlings in medium soils with removing weeds (hand loosening)	1,000 m^2	3.331	846.52 / 846.52	- / -	2,820	2,820	- / -	19.9650 / -	66.50 / -
20	Annual autumn (1-1-1-1-1) nonmouldboard tillage between the rows and in edges in medium soils, for the five years	km	20.82	121.87 / -	121.87 / 29.96	2,537	-	2,537 / 624	- / 0.5084	- / 10.58
	Total direct costs according to the estimates:					59,841	3,843	12,926 / 3,341		88.98 / 56.74
	Total direct costs				UAH	59,841				
	Cost of materials, products and facilities				UAH	43,072				
	Total labour costs				UAH		7,184			
	Overall production costs				UAH	3,287				
	Labour intensity in overall production costs				man-hours					12.82
	Labour costs in overall production costs				UAH		1,045			
	TOTAL by cost estimates				UAH	63,128				

No.	Name of works and costs	Unit	Number	Cost per unit (UAH)		Total cost (UAH)			Labour costs for workers not employed in machine maintenance (man-hours)	
				Total	Machinery operations	Total	Labour costs	Machinery operations	Employed in machine maintenance	
				Labour costs	Including labour costs			Including labour costs	Per unit	Total
1	2	3	4	5	6	7	8	9	10	11
	Estimated labour intensity				man-hours					159
	Estimated labour costs				UAH		8,229			

Annex V W Cost-benefit analysis for Climate-Smart Irrigation technology

Table V W-01. Irrigation norms for conventional agriculture, m3/ha (MAPU 2008)

Crop	Southern Steppe	Northern Steppe	Average
Winter wheat	2000-2400	1800-2300	2100
Corn	2000-2600	1800-2400	2200
Spring barley	1100-1500	900-1400	1200
Soy	2400-3000	1900-2600	2450
Sunflower	2000-2700	1700-2400	4400

Table V W-02. Composition of irrigation systems and capital investments required

	Conventional irrigation with fertilization, UAH	Source of information (where applicable)	Climate-smart irrigation with fertilization, UAH
Rainfed equipment (USD 600/ha)	USD 600/ha*1000 ha *26 UAH/USD	Dykalenko 2018	USD 600/ha*1000 ha *26 UAH/USD
Pipelines and hydrants for water intake, USD 600/ha	USD 600/ha *1000 ha * 26 UAH/USD	Dykalenko 2018	USD 600/ha*1000 ha *26 UAH/USD
Installation of pump stations, USD 200/ha	USD 200/ha *1000 ha *26 UAH/USD	Dykalenko 2018	USD 200/ha *1000 ha *26 UAH/USD
Fertilizer distributors, 5 units	5*473000 UAH		5*473000 UAH

GPS Mg Navigator V2 with receiver GeoX4	-	T&T 2020	41 400
Weather station IMT300	-	SmartWell LTD (2020)	114 000
Offset ECOD3, 200 items	-		200*19 000 UAH
Board interface connection, 201 items	-		201*38 000 UAH
Soil sensor SENTEK DRILL & DROP, 201 items	-		201*13 000 UAH
Installation, UAH	34888500		52 354 260
Total, UAH	73 653 500		110 525 660

Table V W-03. Costs for crop cultivation with conventional irrigation

	Winter wheat	**Barley**	**Corn (for grain)**	**Soy**	**Sunflower (for seeds)**
Labor costs, UAH/ha	525	525	900	675	375
Seeds, UAH/ ha	1440	1375	5500	1834	1115
Fertilizers, UAH/ha	3075	3075	5000	3075	3075
Crop protection agents, UAH/ha	1100	1000	1650	4125	1925
Water, UAH/ha	4100	3300	4400	4900	8800

Fuel, UAH/ha	1120	1200	2880	2560	960
Maintenance, UAH/ha	1500	1600	2500	2200	1550
Total	12860	12075	22830	19369	17800

Source: own calculations based on (Sidorenko, Lilevman 2018). 2019 prices were used.

Table V W-04. Production costs under conventional irrigation, UAH

	Winter wheat	**Barley**	**Corn (for grain)**	**Soy**	**Sunflower (for seeds)**
Rent for arable land	413000	413000	413000	413000	413000
Insurance payments	643	603,75	1141,5	968,45	890
storage and sales	643	603,75	1141,5	968,45	890
other costs	1286	1207,5	2283	1936,9	1780
other production costs (social payments, compensation of wastes)	643	603,75	1141,5	968,45	890
Total	416215	416018,8	418708	417842,3	417450

Source: own calculations based on (Sidorenko, Lilevman 2018). 2019 prices were used.

Table V W-05. Economic indicators of crops cultivation under conventional irrigation

	Winter wheat	**Barley**	**Corn (for grain)**	**Soy**	**Sunflower (for seeds)**

Operational costs, UAH	12860	12075	22830	19369	17800
Production cost, UAH	416215	416018,75	418707,5	417842,25	417450
Yield, t/ha	3,4	3,3	5,5	3	2,5
Area, ha	200	200	200	200	200
Gross collection, t	680	660	1100	600	500
Sales price, UAH/t	5520	4970	4195	8775	10100
Gross income, UAH	3753600	3280200	4614500	5265000	5050000
Profit, UAH	3324525	2852106,25	4172963	4827788,75	4614750

Source: own calculations

Table V W-06. Costs of crop cultivation with climate-smart irrigation

	Winter wheat	**Barley**	**Corn (for grain)**	**Soy**	**Sunflower (for seeds)**
Labor costs, UAH/ha	525	525	900	675	375
Seeds, UAH/ ha	1440	1375	5500	1834	1115
Fertilizers, UAH/ha	3075	3075	5050	3075	3075
Crop protection agents, UAH/ha	1100	1000	1650	4125	1925
Water, UAH/ha	2050	1650	2200	2450	4400

Fuel, UAH/ha	1120	1200	2880	2560	960
Maintenance, UAH/ha	1500	1600	2500	2200	1550
Total	10810	10425	20680	16919	13400

Source: own calculations based on (Sidorenko, Lilevman 2018)**.** 2019 prices were used.

Table V W-07. Production costs under climate-smart irrigation, UAH

	Winter wheat	Barley	Corn (for grain)	Soy	Sunflower (for seeds)
Rent for arable land	413000	413000	413000	413000	413000
Insurance payments	540,5	521,25	1034	845,95	670
Storage and sales	540,5	521,25	1034	845,95	670
Other costs	1081	1042,5	2068	1691,9	1340
Other production costs (social payments, compensation of wastes)	540,5	521,25	1034	845,95	670
Total	415703	415606,3	418170	417229,8	416350

Source: own calculations based on (Sidorenko, Lilevman 2018)**.** 2019 prices were used.

Table V W-08. Economic indicators of crops cultivation under climate-smart irrigation

	Winter wheat (Kernasyuk 2018)	Barley (Blazhko 2019)	Corn (for grain) (Kernasyuk 2018)	Soy (UCAB 2020)	Sunflower (for seeds) (UCAB 2020)
Operational costs, UAH	10810	10425	20680	16919	13400

Production cost, UAH	415702,5	415606,25	418170	417229,75	416350
Yield, t/ha	3,4	3,3	5,5	3	2,5
Area, ha	200	200	200	200	200
Gross collection, t	680	660	1100	600	500
Sales price, UAH/t	5520	4970	4195	8775	10100
Gross income, UAH	3753600	3280200	4614500	5265000	5050000
Profit, UAH	3327087,5	2854168,75	4175650	4830851,25	4620250

Source: own calculations

Annex VI. TNA team contacts

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Annex VII. Working group – agriculture sector

Combination of Conservation Agriculture with drip irrigation,			
DICA technology workshop (December 23, 2019, Kherson, Mykolaiv)			
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Implementation of agroforestry practices **Agroforestry technology workshop (December 09, 2019, Kyiv-Kharkyv)**			
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Serhii Shmatenko	Vinogradovsky village head	Head	

Annex VIII. List of Experts Participated in Barrier Analysis and Enabling Framework for Adaptation Technologies in Water Sector

Name	Affiliation	Position	Comments on Consultations
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Shevchuk Sergii	The Institute of Water Problems and Land Reclamation	PhD in Technical Science, the Head of Water Resource Department	In person interviews and discussions, electronic mail exchange
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Didovets Yulii	The Potsdam Institute for Climate Impact Research	PhD in Hydrology, Researcher	In person interviews and discussions, electronic mail exchange
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Yuschenko Yuriy	Yuriy Fedkovych Chernivtsi National University, Chernivtsi	DSc in Geography, the Professor, Head of Hydrometeorology and Water Resources Department	In person interviews and discussions, electronic mail exchange
Shevchenko Olga	The Taras Shevchenko National University of Kyiv, Kyiv	DSc in Geography, Associate Professor	In person interviews and discussions, electronic mail exchange
Manivchuk Vasyl	The Transcarpathian Regional Center of Hydrometeorology, Ushgorod	MSc in Hydrology, Head	In person interviews and discussions, electronic mail exchange
Semenova Inna		DSc in Geography, Professor	
Gopchak Igor	The National University of Water and Nature Management, Rivne	PhD in Geography, Associate Professor	In person interviews and discussions, electronic mail exchange

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Sherstyuk Nataliya	Oles Honchar Dnipro National University, Dnipro	DSc in Geography, Professor, the Dean of Faculty of Geology and Geography	In person interviews and discussions, electronic mail exchange