Co-funded by the European Union

THE MINISTRY OF TERRITORIAL ADMINISTRATION AND INFRASTRUCTURE OF ARMENIA

THE MINISTRY OF ECONOMY OF THE REPUBLIC OF ARMENIA

REPUBLIC OF ARMENIA MINISTRY OF ENVIRONMENT

Գերմանական համագործակցություն DEUTSCHE ZUSAMMENARBEIT giz

FEASIBILITY STUDY ON CULTIVATION OF AGRICULTURAL CROPS TO SERVE BOTH FOR AGRICULTURAL AND ENERGY PURPOSES

Armenian National Agrarian University
Final Report

31 July 2023

EU4Energy Efficiency and Renewable Energy in Armenian Communities

CONTENTS

This material was created within the framework of the "EU4Energy Efficiency and Renewable Energy in Armenian Communities" project financed by the European Union (EU) and the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH as a part of the "ECOserve" programme.

LIST OF FIGURES

EXECUTIVE SUMMARY

The programme “Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus” (ECOserve) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH GIZ is a part of the wider German support in the priority area “Environmental policy, conservation and sustainable use of natural resources in the South Caucasus”. The program is dedicated to enhancing the management of natural resources, thereby ensuring economic, environmental, and social benefits for rural communities in Armenia. The project “EU4Energy Efficiency and Renewable Energy in Armenian Communities” is implemented with the financial support of the European Union (EU) and the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH as a part of the “ECOserve” programme.

Within the EU co-financed project, the Armenian National Agrarian University conducted a feasibility study on cultivating agricultural crops for technical and energy purposes. The study focused on assessing the viability of cultivating various agricultural crops that could serve food, feed, technical, and energy-related objectives. It included a comprehensive cost-benefit analysis and presented recommendations for potential pilot activities.

This final report developed within the study's framework, encompasses a comprehensive review of relevant literature, international and local program/research reports, and practical experiences. It includes technical and financial feasibility analyses, justifications, and a pilot concept for selected crops. Throughout the study, various types of crops were considered, with a focus on their suitability for food, fodder, and renewable energy purposes. The research prioritized agricultural crops with the potential to yield the highest biomass and demonstrate adaptability to the region's agri-climatic conditions. To ensure the accuracy and validity of the findings, interviews were conducted with representatives from diverse professional groups, including agronomy, environmental protection, sectoral policy development, and alternative biofuel production, among others. These interviews enhanced the reliability and depth of the study's results. The main activities conducted during different stages of the research are summarized in Appendix 1.

Based on the findings of the feasibility study, four field crops were selected: Maize, Sunflower, Sorghum, and Jerusalem Artichoke. The choice of these crops was based on their high productivity of vegetative mass, their adaptability to diverse agro-climatic zones, and their potential to generate substantial income for farmers. A pilot concept was developed to be implemented in different regions of Aragatsotn, Kotayk, Shirak, Lori and Tavush marzes of Armenia, taking into account the existing briquetting facilities.

Additionally, the expert group at ANAU specifically examined the production possibilities of lesser-known crops in Armenia, such as Amaranth, Quinoa, Miscanthus, and Paulownia.

1. INTRODUCTION

Agriculture at Glance

To gather comprehensive information about agricultural residues in the Republic of Armenia, it is essential to have a glance on the trends in agricultural development over the past 5 years. This is crucial as various sub-sectors of agriculture, including crop and animal husbandry, significantly contribute to the formation of residual biomass, which holds potential for both technical and energy applications. By analyzing the overall agricultural landscape, we can better understand the availability and utilization of these valuable resources for various purposes.

Agriculture has a central role in the economic and social aspects of Armenia contributing around 11% to the GDP and 24% to the overall employment of the country (WB, 2021). The landscape, relief and the climatic conditions of Armenia promote the diversity in the ecosystem and cultivation of various plants to be used for food, fodder and energy purposes.

The Gross Agricultural Output (GAO) of Armenia in 2021 was 934,400 billion AMD, where the share of crop production was about 50.2%. After 2017, the gross agricultural output in Armenia continuously decreased until 2021, when there was around 101,000 million AMD increment in GAO in monetary terms in 2021.

Crop Production has a crucial role for the food security and self-sufficiency of the country. Symmetrically with the GAO, the crop production in the last few years has been decreasing; however, it had a drastic increase in 2021, which can be described by the return of the labor migrants from abroad during the pandemic.

Armavir and Ararat marzes have the biggest share in crop production followed by Gegharkunik and Aragatsotn Marzes. In the grain and leguminous plants category, the winter and spring wheat has the biggest share followed by winter and spring barley and maize for grain. Oats, spelt and legumes have relatively low quantity. It is noteworthy that in terms of the gross harvest of grains and leguminous plant, Lori Marz holds the first position. Shirak and Syunik have the next highest gross harvest indicators.

In Armenia, vegetable cultivation is carried out in two main ways: in the open field and in the regulated system of protected soil (greenhouses and hothouses). During the last five years, greenhouse enterprises equipped with modern technologies have been developing, where various vegetable, fruit and flower crops are grown all year round. In the years 2011-2019, the area of greenhouses and hothouses in the whole country increased from 30 ha to 1300 ha. Tomatoes, cucumbers, peppers, eggplants, berries, strawberries, various greens and leafy vegetables, as well as flowers, such as rose, gerbera, dianthus, alstroemeria are the main crops produced in greenhouses and hothouses.

Most forage crops fall into the category of roughage, hay, and green forage, with the largest portion being hay collected from natural grasslands, unused arable land, and other land. Shirak and Lori marzes occupy more than 30% of the fodder cultivation area. The regions of Amasya and Ashotsk have the largest share of crops used for fodder.

Fruit and grape production in Armenia is mainly developed in the plain, foothills and north-eastern regions. In recent years, in Ararat, Armavir, Aragatsotn, Kotayk and Tavush marzes, intensive orchards of walnut, almond, pistachio, apple, apricot, pear and plum production have been developed.

Energy Sector at Glance

Energy sector is a key focus of the conducted research, as the project's ultimate goal is to utilize agricultural residues to produce bioenergy products that contribute to sustainable community development and environmental protection.

Armenia's energy sector heavily relies on imported fossil fuels, with natural gas being the predominant component. In 2021 the imported energy resources made 81.2% of the primary energy supply. The internal energy production includes hydropower, nuclear power, and solar energy. Gas and oil products are entirely imported.

While efforts have been made in recent years to increase renewable energy production, it still constitutes a relatively small portion of the overall energy mix.

According to the energy balance, in 2021 households were the largest sector of energy consumption, accounting for 34.7% of the final energy use. The share of the transport sector was 32.5%, the service sector was 15.7%, and the share of the industry sector was 13.4%.

According to UNDP (2017), Armenia's estimated renewable energy capacity is 4300 MW, with installed capacities of 12.6 MW for wind and biogas.

Bioenergy sources in Armenia are diverse, with significant raw material potential available from specialized crop-producing farms in the form of residual biomass, livestock farms providing manure, and fish farms, among others.

Agricultural residues, including post-harvest leftovers from crop and vegetable production, fruit and vineyard pruning branches, and plant residues from forest ecosystems, play a crucial role in bioenergy production in Armenia. These resources hold particular importance in harnessing sustainable bioenergy and supporting Armenia's renewable energy goals.

2. AGRICULTURAL RESIDUES FOR BIOENERGY PRODUCTION

Agricultural residues are carbon-based biomass that are generated as a result of various agricultural activities such as harvesting, processing or storing. The biomass generated from the harvesting are called primary or field-based residues. The residues accumulated after the processing or storing are secondary. Agricultural residues are very diverse and heterogeneous in terms of bulk density, moisture content, particle size and distribution relative to operational activities. Usually the field residues are not used as fodder, or fertilizers. On the contrary, almost half of these resources are burnt on the field prior the next farming season. This, in essence, causes both lost economic opportunities and environmental concerns.

Varying with their chemical compositions, age, length and some other physical properties, residues have high perspective for bioenergy purposes. Agricultural residues are diverse can be produced from food crops such as maize, wheat, sunflowers, and so on.

The benefits of using agricultural residues are diverse: one of the major benefits is that they are not competing with the food crop production. If reused properly, they can even drop the costs of food crop production, due to self-sufficient on-farm energy demand. The amount of agricultural residues is very subjective to a particular geographic area, and depends on several factors. Usually, there are scientifically accepted coefficients for harvest-residue ration.

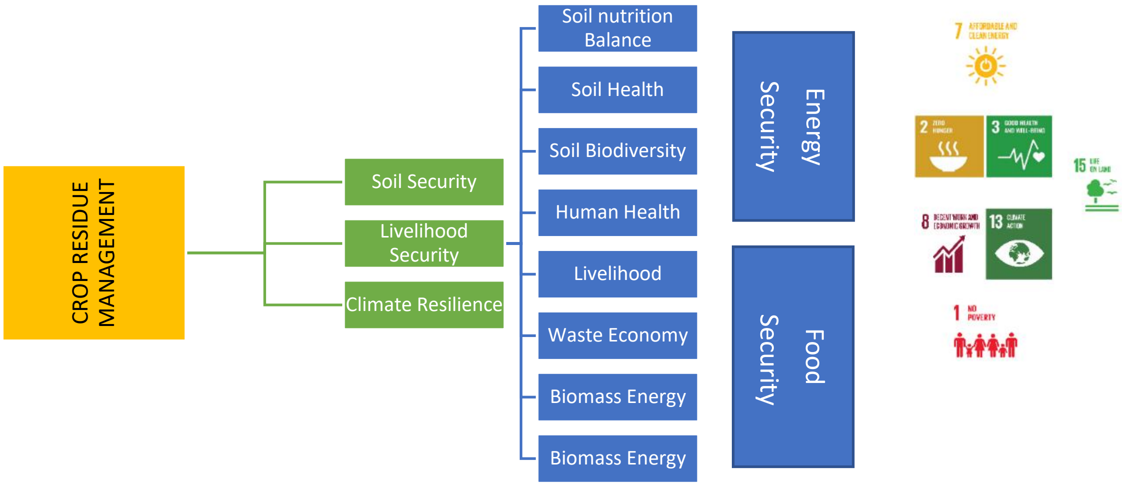
It is noteworthy that crop residues are not the only biomass sources for energy production. Orchard residues especially from the pruning activities are also valuable source for renewable energy.

Globally, the biomass quantity is projected to increase because of the rising food demand, mechanization of agricultural production, and lack of resources among farmers, that have small or medium farm size.

However, with projected increase in the biomass quantity, there is the need to find other sustainable alternatives for the biomass application at a larger scale with the circular bio economy approaches such as carbon sequestration, bioenergy production (especially in the form of bio briquettes and pellets in marginalized societies), soil and water conservation.

The figure below shows that the proper management of the crop residues as well as other agricultural remnants can bring many benefits to the ecosystem and the society. Bio-economy approaches towards the massive biomass generated from conventional agriculture, will eventually promote two strategic macro-level indicators: Energy and Food Security.

In the bio economy model, farmers will increase their livelihood through multi-functional, climate smart and intensified sustainable agricultural production.



Within the scope of studies, in-depth interviews were conducted in collaboration with academia, non-governmental sectors, and business representatives to explore viable methods of obtaining feed and bioenergy from agricultural residues and crops (Appendix 2).

Specific directions for biomass sources were identified, including agricultural crop harvest residues, such as spring wheat, sunflower, and maize, along with vegetative mass residues from various vegetables. These residues are often burned in the fields during the fall, leading to significant environmental hazards and missed economic opportunities. Overall, Armenia possesses an above-average potential for bioenergy production from agricultural residues. However, various hindering processes need to be addressed, which will be discussed further.

Experts raised concerns about the processing of vegetable residues, especially those grown in greenhouses, due to the chemicals added to the soil for higher yields and marketable products. Burning such waste containing chemicals can pose risks to both the ecological system and human health. Another challenge lies in the collection of dry leaves accumulated in villages, given their large quantities and scattered distribution. This logistical barrier exists for almost all sources of biomass, as about 90% of crops and other herbal residues are stockpiled on small farms. While the study mainly focuses on plant biomass, experts mentioned the potential for obtaining biomass from the livestock sector, such as animal manure, fish farming waste, and algae, which could be utilized for small-scale biogas production.

Furthermore, it was noted that biomass can also be collected from coniferous areas, although their quantity is limited, and the collection and transportation processes can be quite challenging. Considering the insights provided by the experts, this research addresses the potential of obtaining biomass in various value chains. The yield calculations were based on coefficients from existing literature, which are presented below.

Table 1: Agricultural residues from crops and calculation coefficients

Crop	Residues	Biomass/Harvest Ratio (t/t of the grain)	Reference Heat (MJ/Kg)
Winter Wheat	Straw	1,5	15
Winter Barley	Straw	1,3	15
Winter Rye	Straw	1,5	15

Spring Wheat	Straw	1,3	15
Spring Barley	Straw	1,2	15
Spring Rye	Straw	1,2	15
Oats	Straw	1,4	15
Spelts	Straw	1,5	15
Maize for grains	Straw	1,3	16,8
Sunflowers	Straw	1,4	16,2

To calculate the biomass potential of the grains, the average gross harvest of the past 5 years was calculated and multiplied by the coefficient. This amount shows the technical potential of the biomass yield.

Table 2: Biomass yield from crops (2017-202)

Crops	Gross Harvest	Biomass quantity (t)	Gross Harvest	Biomass quantity (t)	Gross Harvest	Biomass quantity (t)	Gross Harvest (t)	Biomass quantity (t)	Gross Harvest (t)	Biomass quantity (t)	Gross Harvest (t)	Biomass quantity (t)
	2017	2017	2018	2018	2019	2019	2020	2020	2021	2021	2017-2021	2017-2021
Winter Wheat	169928	254892	182168	273252	110350	165525	129146	193719	193719	290579	159206.5	235593.4
Winter Barley	5380	6994	4593	5971	3967	5157	3681	4785	4785	6221	4631	5825.6
Winter Rye	68	102	149	224	161	242	221	332	332	498	166.5	279.6
Spring Wheat	6500	8450	5285	6871	2271	2953	2805	3647	3647	4741	4501.3333	5332.4
Spring Barley	87551	105061	119574	143488	64366	77240	86305	103566	103566	124279	91485.5	110726.8
Spring Rye	260	312	693	832	26	32	65	77	77	93	230.16667	269.2
Oats	5854	8196	4899	6858	3388	4743	6178	8649	8649	12108	5803.6667	8110.8
Spelts	11598	17396	9300	13950	5669	8504	7005	10507	10507	15761	9279.5	13223.6
Maize for grains	10413	13537	7586	9862	4718	6133	6357	8264	8264	10743	7958.5	9707.8
Sunflowers	2205	3087	1537	2151	2126	2976	1824	2554	2554	3575	2075.1667	2868.6
Total	**299757**	**418027**	**335784**	**463459**	**197042**	**273505**	**243587**	**336100**	**336100**	**468598**	**285337.83**	**391937.8**

The table above shows that in 2021 the biomass quantity in the forms of straw from the cereals post-harvest is 468,598 tons in total, which has increased by 12% compared to 2017. Given that around 50% of the generated straw will be used for as fodder for the livestock, the rest of the biomass is left on the field. This shows that technically half of it can be used for energy purposes.

In addition to the above-mentioned crops, other value chains have been identified, the residual biomass of which can be used for energy purposes. Among them are residual biomass from orchards and vineyards, mainly in the form of pruned branches.

Let's take a closer look at the residues from the orchard management practices including vineyards.

Table 2: Residual Biomass from Fruit Orchards and Vineyards

Type	Biomass Residues	Biological Waste Coefficient (t/ha)	Heat Capacity (MJ/Kg)
Fruit Trees	Branches	1,2	17,9
Vine	Branches	0,8	15

	Residues of fruit-bearing orchards in Armenia (tons)					
	2017	**2018**	**2019**	**2020**	**2021**	**Average**
Yerevan	1542	1542	1542	1542	1542	1542
Aragatsotn	8382	8446,8	6392,4	6656,4	6726	7320,72
Ararat	8430	8610	8938,8	8934	9280,8	8838,72
Armavir	8952	8907,6	9021,6	9092,4	9374,4	9069,6
Gegharkunik	1598,4	1588,8	1681,2	1680	1669,2	1643,52
Lori	2391,6	2390,4	2396,4	2389,2	2392,8	2392,08
Kotayk	4530	4455,6	4773,6	4730,4	4861,2	4670,16
Shirak	753,6	726	648	718,8	687,6	706,8
Syunik	2758,8	2793,6	2808	2817,6	2839,2	2803,44
Vayots Dzor	2329,2	2367,6	2415,6	2437,2	2448	2399,52
Tavush	2764,8	2997,6	2961,6	2974,8	3016,8	2943,12

Residues of vineyards		2018	2019	2020	2021	Average
Republic of Armenia	12651,2	12879,2	13197,6	13344,8	13219,2	13058,4
Yerevan	76,8	76,8	76,8	76,8	76,8	76,8
Aragatsotn Marz	1002,4	1160,8	1146,4	1127,2	1207,2	1128,8
Ararat Marz	3770,4	3717,6	3840	3879,2	3884,8	3818,4
Armavir Marz	5433,6	5539,2	5783,2	5920,8	5748,8	5685,12
Gegharkunik Marz	0	0	0	0	0	0
Lori Marz	53,6	53,6	53,6	53,6	53,6	53,6
Kotayk Marz	135,2	124,8	118,4	108,8	63,2	110,08
Shirak Marz	0	0	0	0	0	0
Syunik Marz	143,2	144	143,2	143,2	144	143,52
Vayots Dzor Marz	960	971,2	961,6	961,6	964	963,68
Tavush Marz	1076	1091,2	1074,4	1073,6	1076,8	1078,4

In general, it can be noted that the potential of bioenergy production from agricultural residues in Armenia is higher than average, but there are many hindering factors, which have been assessed by experts.

Key Obstacles

Although the potential for using biomass for bioenergy is high in Armenia, experts have identified a number of obstacles that are summarized in five areas: **legislation and policy, technology and resources, logistical obstacles, lack of business models, lack of educational resources.**

Legislation and policy: The majority of experts noted the lack of legislation and relevant policies as the biggest obstacle to the transition to a more sustainable energy system in Armenia. It was noted that there are no control mechanisms in this area. Mostly, crop residues are subjected to burning, affecting topsoil, which is a huge threat to the food-soil-energy nexus in Armenia. Most farmers are unaware of the great damage they are causing to the environment, as it takes an average of 50-100 years to develop one cm of topsoil, which contains the most organic matter and micro-organisms. **Technology and resources.** The small volumes that accumulate in fragmented farms prevent their efficient use, especially for energy purposes. In addition, despite the large amount of uncultivated arable land, cereals are cultivated at about 30% self-sufficiency level. There are many reasons, but the main one is the low technological level of cultivation, which if applied correctly, it will be possible to get a sufficient harvest with lower costs.

Logistical obstacles. One of the main obstacles to harvesting biomass from different value chain residues (crops, pruned trees, vineyards, etc.) is their transportation. It may increase the price of biomass-derived solid fuel, which may lead to its limited competitiveness with traditional fossil fuels. In addition, experts note that the commodity exchange system, such as fuel for raw materials, is not developed in the communities, while this could be the basis for the further development of the sector. Recycling straw as waste fuel will also help reduce costs. One expert states that "correct cultivation of one hectare of wheat will lead to the formation of enough straw, which will provide energy equivalent to up to 5 m^3 of energy obtained from burning wood." Today, more than 200,000 ha of arable land with high yield indicators are not cultivated in Armenia." [1]

Lack of business models. There are no well-defined schemes in Armenia for supply chains, biomass mobilisation, acquisition of financial resources, investment proposals and risk mitigation plans.

Lack of educational resources. One of the obstacles is also the lack of sufficient knowledge, skills and capacities among farmers and enterprises.

Despite the diverse obstacles to using biomass as a renewable energy source, the experts express optimism about the sector's development in the coming five years. They believe that during this period, effective technologies can be adapted and implemented, and technical and human capabilities can be improved. However, before proceeding, a thorough economic assessment of biomass sources is necessary to pave the way for larger-scale projects. These assessments will help fine-tune strategies and introduce suitable incentives. Regarding food security, experts recommend prioritizing the utilization of crop residues for energy purposes without diverting arable land for the production of

[1] This refers to the average index of residual straw obtained from 1 ha of winter wheat cultivated in arid agricultural areas. The ANAU expert team considers it necessary to note that it is possible to obtain even higher indicators in both dry and wet conditions, based on the fact that according to literature data, the energy released from the combustion of each 1 ton of solid fuel made from straw is equal to about 3.3 cubic meters to the energy obtained from firewood.

specific energy crops. Exceptions could be made for energy crops showing medium to high growth potential in marginal soils.

In the second stage of the study, crops suitable for fodder, food, technical, and energy purposes were identified. The main focus was on strategically important crops for food security that also provide substantial biomass for fodder and energy. These crops demonstrated adaptability to different agro-climatic conditions in Armenia and proved economically viable.

The expert group emphasized factors such as climate change adaptability, cultivation possibilities in various agro-climatic zones, and overall profitability as essential indicators.

The preliminary list of field crops based on botanical families includes cereals like wheat, barley, sorghum, buckwheat, rye, oats, wheat bran, and maize; oilseeds like sunflower and safflower; and legumes like Jerusalem artichoke and potato.

After conducting the research, Maize, Sorghum, Sunflower, and Jerusalem Artichoke were selected among the mentioned field crops. The criteria for their selection were based on:

- Agro-climatic and soil conditions, including water requirements
- Applicability for food, feed, and energy production
- Indicators of residual vegetative biomass
- Percentage yield of commodity products from a unit of raw dry biomass
- Adaptability to climate change

These selected crops offer promising potential for biomass production and energy generation in Armenia's diverse agro-climatic conditions.

3. CHARACTERISTICS OF THE SELECTED CROPS

3.1 Maize

Maize is an annual, heat-loving crop of the Poaceae family, with a high yield and high value for food, fodder and technical significance. In RA, it is mainly cultivated in the irrigated conditions of the Ararat valley and the foothills, in the irrigated conditions of the Sevan, Gavar, Martun, Artik, Spitak and Ijevan regions, as well as in the arid conditions of the relatively rainy regions of Hrazdan, Tumanyan, Noyemberyan and Berd. In Armenia, it is possible to cultivate in agro-climatic zones with an altitude of 450-2000 m above sea level.

Application

Grain, flour and oil are used for food purposes acquired from Maize. Green mass is a juicy feed for farm animals. The green mass collected during the milky ripening stage of the sides serves as a good juicy fodder for ensiling. The grain is used as a concentrated feed in the crushed form. In the milk stage, it gives the highest yield of green mass: 50-80 t/ha and more. Grain yield can reach 4-6t/ha, with good cultivation up to 8t/ha and more. The duration of vegetation of different maize varieties and hybrids is 90-140 days. Varieties and hybrids are classified as early-ripening, mid-ripening, mid-ripening and late-ripening according to the duration of grain ripening. The older the varieties are, the higher the amount of vegetative mass they form. It is a short-day plant, it belongs to the group of drought-resistant plants. Maize grows well and produces high yields in loose and fertile soils, in waterlogged conditions, or in dry conditions in regions with sufficient moisture. In the case of cultivation for grain, a huge bulk biomass is produced after harvest, stems and leaves with rich membrane, which is partly also used as coarse bulk feed, and the main production volumes can be the best feedstock for biomass fuel because of its high energy value. Each kilogram of dry biomass provides 16.7 MJ of energy.

Cultivation technology and conditions

The best areas for cultivation are the irrigated parts of the lowland and foothill zones, as well as the arid areas of the relatively humid post-forest zones of the north-eastern region and Lori marz. It is a heat-loving, spring crop, the transpiration coefficient varies between 160-360 depending on the variety and cultivation conditions. As a spring crop, soil preparation for cultivation should include deep plowing in the late summer or fall of the year prior to planting, during which the main organic (manure) and mineral (PK) fertilizers are introduced into the soil. At the first opportunity to go out into the field in the spring, the field is raked, after which cultivation is carried out 1-2 times (depending on the weediness of the field) before sowing. To obtain seeds, sowing is usually done in a wide row or dotted way, with a distance of 60-70 cm between rows and 25-30 cm between plants, with a seed rate of 15-25 kg/ha (depending on the size of the seed). To get green fodder, the sowing rate is up to 40 kg/ha and more. During the growing season, one of the main cultivation works is the loosening of the inter-row areas (2-3 times) and feeding with nitrogen fertilizer (N). Selective herbicides should be used against possible weeds in the field. In dry zones, it is irrigated 4-6 times with a rate of 500-800m^3. Harvesting for obtaining grain is done at the stage of full ripening of the grain.

In the Republic of Armenia, maize is mainly cultivated for the purpose of obtaining green mass (silage raw material), straw (as feed) and grain (concentrated fodder) in limited areas. It is mainly cultivated in the Ararat plain and the north-eastern regions. The average grain yield for the last three years, 2019-2022, was 4.1-5.2 t/ha, and the sown areas were 1250 ha, the total grain yield was 6500 t.

The indicated volumes are too small to meet the demand in RA, especially from the point of view of feed production. Cultivation in limited areas is due to lack of seed material, irrigation problems, as well as fertilization and other cultivation difficulties. Sufficient land areas are available in the regions of possible coverage for cultivation of the crop. There is a possibility to grow more, but the limitations of the possibilities (seed material, fertilizers, irrigation possibilities, high price of energy carriers, stable supply possibilities) do not allow the expansion of cultivated areas. Currently, maize residue biomass is not largely used for energy purposes, as biofuel producers from plant feedstock are more specialized in using other crops and production residues (mainly wheat straw, sawdust, tree and vine prunings). The current cultivation of the maize crop with limited areas in different regions is mainly used for green fodder, and in the case of cultivation for grain and grain, the residual dry mass formed after harvesting, stems and leaves, is partly used as coarse bulk feed (after crushing or grinding), and partly directly is covered as an organic mass. Unused residual mass as production waste is relatively small and is not concentrated in any region, but is present in different marzes and regions, the costs associated with its collection and transportation are quite high (according to producers' comments). In general, the briquetting points operating in Armenia almost have a narrow specialization based on the vegetative mass of certain plant species and the raw material base with the production residues of the plant breeding sector. In the event of the implementation of the new pilot, the demand for the energy-important biological mass for briquetting points will be determined by the accessibility and cost of this mass. Some entrepreneurs engaged in briquette production are ready to procure the remaining vegetative mass of maize as raw material, if the raw material volume, sales price and transportation costs are economically justified. The technical indicators of the crop are summarized in the table below:

Table 3: Technical indicators of Maize and its technological card

Crop	Duration of vegetation (DVM)	Dry vegetative Mass	Irrigation and heat requirements	Energy value of biomass, MJ/kg	Briquetting potential
Maize	90 -140 days	15000-16000kg/ha	500-800m3/ha, it is a heat-loving plant	16.7 MJ/kg	~ 14t/ha

Materials or activities	Unit	Unit Cost	Quantity (kg, ha, cubic meter)	Total Cost, AMD
Seed	kg	3000	25	75000
Fertilization from the field: Phosphorous	kg	280	200	56000
Fertilization from the field: Potassium	kg	280	150	42000
Tillage: main tillage, leveling	ha	55000	1	55000
Organic fertilizer/Manure	kg	20	20000	40000
Fertilization with manure	ha	20000	1	20000
Soil surface treatment with herbicide	ha	10000	1	10000
Herbicide	kg	3500	2	7000
Sow	ha	20000	1	20000
Cultivation of inter-row spaces: 2 times + nutrition	ha	15000	3	45000
Nitrogen fertilizer	kg	180	250	45000
Watering: 6 times	cubic meter	11	4800	52800
Salary of the worker for irrigation	ha	10000	6	60000
Harvesting	ha	40000	1	40000
Transporting the yield	kg	8	4000	32000
Harvest filtering, canning	kg	10	2500	25000
Land tax	ha	23000	1	23000
Transportation and other expenses	-	-	-	30000
Total costs	-	-	-	**677800**

Cost - benefit analysis shows that the cost of 1ha maize cultivation is 677800 AMD, while the revenue generated from the grain sales is 1400000 AMD which may secure 106.5% gross profit. In addition, 15000-16000 kg/ha vegetative mass (stem, leaves) is generated with 16.7 MJ per kg energetic value if used as a raw for briquetting. According to the producers' suggested sales price (20 AMD/kg), the additional revenue from the sale of biomass at the briquetting sites will be between AMD 300000 and 320000. Large farms in RA (like those in the Yeremyan Project) can produce such a volume of goods because they fully fund the operations and investments required by the technological card. Small and medium farms, on the other hand, rarely achieve such production levels because they frequently lack or only partially fund the sophisticated technological tools required for crop cultivation.

Large farms in Armenia (e.g., in the Yeremyan Project) provide such a volume of products, because they fully provide the operations and investments in line with the technology card. Small and medium farms do not provide or partially provide the complex technological measures necessary for crop cultivation.

3.2 Sunflower

Sunflower is an annual plant belonging to the Asteraceae family. About 50 species of sunflower are known. In the Republic of Armenia, mainly oil-bearing varieties are cultivated mostly in the Ararat valley and in the north-eastern regions of the country. The local agro-climatic conditions, as well as the variety, influence the length of the vegetation period and the requirement for heat. The favorable temperature for plant growth is considered to be 18-26 °C. The plant does not tolerate high heat, while some varieties tolerate drought well, thanks to the roots that penetrate to the deep layers of the soil.

Sunflower cultivars are categorized into four groups based on the length of their vegetative period: super-early, early, mid, and mid-late (90-140 days). It is mostly grown in the irrigated conditions of the Ararat valley and foothills, as well as in the arid regions of the comparatively rainy districts of Hrazdan, Sevan, Gavar, Martuni, Aparan, Tumanyan, Noyemberyan, and Berd. In Armenia, agroclimatic zones between 500 and 2000 meters above sea level are suitable for cultivating sunflower.

<u>Application</u>

It is processed for food, fodder and technical purposes. Oil is obtained from the seeds, which is used in the food industry (canning, margarine, baking, etc.) and in the production of soap, varnishes and paints. The seeds are also used in confectionery production. Sunflower residues (stem, leaf, receptacle residues, seed shells) is used to obtain paper, rubber, potash. Sunflower residual basket is a good quality concentrated feed, and the seeds are used in the production of concentrated-combined feed. High-quality canned feed - silage - is obtained from the green mass. Depending on the cultivation conditions, the applied agro-technique provides a harvest of around 40-80t/ha of green mass. In case of cultivation for seed, after harvesting the seed receptacles, the residual vegetative dry mass (stems, leaves) is about 17-35 t/ha. The dried vegetative mass (stems, leaves and receptacles) has a high energy value, each kilogram provides 16.8 MJ of energy and as agricultural residual biomass can be fully used as raw material for obtaining biofuels.

The husks of the sunflower are products that can be used for pelleting due to their high calorific value. The heat amount of 1 ton of the husk pellet combustion is the same as burning 685 liters of fuel oil, 500 liters of diesel fuel, 479 cubic meters of natural gas, and 1600 kg of timber.

As an agricultural residue, the husks of sunflowers do not require extra costs in terms of the solid biofuel production. The pellets and briquettes from the sunflower husks are safe both chemically and biologically. The following characteristics of sunflower husk briquettes have been observed:

- The heat of combustion (MJ/kg): ≥ 17.5-22.00
- Moisture (%): ≥ 10
- Ash (%): ≥ 3,0
- Durability (%): 95

<u>Cultivation technology and conditions</u>

Sunflower is a perennial crop that is mostly grown in arid settings at medium and high altitudes, as well as in the republic's lowland zones with access to water. Although it is not especially demanding for soil, it grows poorly in swamps and calcareous soils. In case of seed cultivation, soil preparation entails thorough plowing (22–25 cm) carried out in the preceding autumn, during which 20–30 t/ha of organic fertilizer (manure) is added to the soil. Raking is done as soon as the field is accessible in the spring, followed by pre-sowing cultivation, raking, and sowing with a spacing of 30–35 cm between plants and 60–70 cm between rows and 20–25 kg/ha of seed at a depth of 7-8 cm.

Because the plants are resistant to late spring frosts, they should be sown as soon as possible. During the vegetative period, inter-row regions are crumbled three times, which can be supplemented with mineral Nitrogen (N) fertilizing. It is irrigated 3-4 times at a rate of 300m^3/ha in low-lying areas with water conditions. When 10-15% of the receptacles have turned gray, seed are ready for harvesting using a combine.

Sunflower production, like that of many other field crops, is currently limited to a small area of the country. The difficulty stems mostly from a scarcity of high-quality seed, the high cost of soil cultivation and fertilization, and difficulties in selling the seed. Although the production of concentrated and combined fodder has increased significantly in recent years in RA, where sunflower seeds are also used in large quantities as ingredients and raw materials, the required volumes of raw materials are still primarily imported from abroad due to the scarcity of local production acreage (the entire area was 623 ha in 2021). It is conceivable and reasonable to cultivate the sunflower crop in all regions of the Republic of Armenia lower than 2000m above sea level agro-climatic zones. The technical indicators of the crop are summarized in the table below.

Table 4: Technical indicators of Sunflower and its technological card

Crop	Duration of vegetation	Dry vegetative mass	Irrigation and heat requirements	Energy value of biomass, MJ/kg	Briquetting potential
Sunflower	90 -140 days	10000-12000 kg/ha	300m3, it is a heat-loving plant, 18-26 °C	16.8 MJ/kg	~9.9 t/ha

Materials or activities	Unit	Unit Cost	Quantity (kg, ha, cubic meter)	Total Cost, AMD
Seed	kg	1200	50	60000
Fertilization from the field: Phosphorous	kg	280	180	50400
Fertilization from the field: Potassium	kg	280	150	42000
Tillage: main tillage, leveling	ha	55000	1	55000
Soil surface treatment with herbicide	kg	20	25000	50000
Organic fertilizer/manure		20000	1	20000
Fertilization with manure	ha	10000	1	10000
Herbicide	kg	3500	2	7000
Sow	ha	20000	1	20000
Cultivation of inter-row spaces: 2 times	ha	15000	2	30000
Nitrogen fertilizer	kg	180	250	45000
Watering: 4 times	cubic meter	11	3200	35200
Salary of the worker for irrigation	ha	10000	4	40000
Harvesting	ha	40000	1	40000
Transporting the yield	kg	8	2500	20000
Harvest filtering, canning	kg	10	2500	25000
Land tax	ha	23000	1	23000
Transportation and other expenses	-	-	-	30000
Total costs	-	-	-	**602600**

The cost-benefit analysis reveals that 1ha of sunflower cultivation requires 602,600 AMD investment, while the expected revenue generated from the sale of the seed and residual cusp (as feed) is around 945,000 AMD providing around 56.8% profit. In addition, 10-12t/ha of vegetative mass (stem leaves) is formed, that may provide 16.8 MJ of energy value per kg in briquette form.

According to the estimated selling price, which is anticipated to be slightly less than wheat straw (20 AMD/kg), the additional revenue from the sale of biomass to briquetting sites will amount to 200,000-240,000 AMD. The studies found that several briquetting locations have tested sunflower residual dry mass as a raw material and are currently prepared to employ it as well in case of significant quantities for reasonable and affordable prices are offered.

3.3 Sorghum

Sorghum is a Poaceae family annual plant. The four species of cultivated sorghum are common, while the most widespread is Sorghum vulgare Pers, which has a vast range of varieties and cultivars used for food, feed, and technological uses. It is a salt- and drought-tolerant, heat-loving crop. Due to its adaptability and high productivity, sorghum is an ideal crop for dry and semi-arid areas. Both the dry conditions of the temperate zones and the moist conditions of the plain and foothill zones can be used to cultivate it in RA. Limited sorghum is currently grown in Armenia, primarily in the Armavir and Ararat regions, primarily for broom production.

Applied significance

Grain sorghum, sugar sorghum, and broom sorghum are the three categories of grown sorghum, respectively. For use as food, both grain and sugar sorghums are grown. In the food industry, sorghum grains and the flour made from them are employed, whereas in the manufacturing of sugar, the extract made from the sweet, juicy stalks is used. Sorghum, grass, and seed green mass is utilized for feed, as well as silage, a luscious, canned feed made from the green mass. Sugars abound in the sorghum crop. In sugar cultivars, the waxy and completely matured stages of grains contain 18 to 24 percent sugar (sucrose, glucose, and soluble starch) in the stem juice. Sulphuric acid can be found in the green mass of certain sorghum species. This is harmful to animals and is more prevalent in some types of broom. By utilizing various growth and harvesting strategies, it is possible to lessen and prevent the buildup of sulphuric acid in fodder kinds as well as render the content innocuous. Broom cultivars are grown for their technical qualities, and their brush-like leaves are used to make domestic brooms.

Cultivation technology and conditions

As a spring crop, the soil should be prepared for cultivation in the late summer or fall of the year before to sowing, when the primary organic and mineral (P40K60 norm) fertilizers are added to the soil. The field is raked at the first chance in the spring, then pre-sowing cultivation is implemented before sowing, Typically, the wider row approach is used to produce grain inflorescence sowing with a seed rate of 10–12 kg/ha. Rows are typically spaced 60–70 cm apart, and plants are separated by 15-20cm. The common row approach, which calls for seeding at a rate of up to 20-25kg per hectare, yields the best results for producing green feed and grass. Raking, inter-row area loosening twice, and feeding (N90 kg/ha) are the primary agricultural tasks during the growing season. It is irrigated 3–4 times in dry areas. Grain is harvested once it has reached its full ripening stage. For silage, it is collected when the grains are waxy mature, and for green mass and grass, it is harvested at the stage of the plants tubering. In terms of broom varieties, harvesting is technically done by direct harvesting when the seeds are fully ripen. It has a vegetative mass yield of up to 30t/ha in dry conditions and up to 100 t/ha in wet conditions. Sorghum has the potential to produce a grain yield of 4.5–5.5 t/ha. Due to the high fiber content in the stems of technical broom cultivars, the resulting biomass has a high energy value, offering 17.3MJ energy per kilogram, and can be the best raw material for the generation of biofuel (after the grain or pods are harvested). This crop may be grown in all agro-climatic zones, especially in arid conditions, and is highly climate change adaptable due to its drought tolerance.

The technical indicators of the crop are summarized in the table below.

Table 5: Technical indicators of Sorghum and its technological card

Crop	Duration of vegetation	Dry vegetative mass	Irrigation and heat requirements	Energy value of biomass, MJ/kg	Briquetting potential
Sorghum	90 -140 days	13000/ha	Heat-loving, drought resistant, salt resistant	17.3 MJ/kg	11 t/ha

Materials or activities	Unit	Unit Cost	Quantity (kg, ha, cubic meter)	Total Cost, AMD
Seed	kg	500	12	6000
Fertilization from the field: Phosphorous	kg	280	200	56000
Fertilization from the field: Potassium	kg	280	150	42000
Tillage: main tillage, leveling	ha	55000	1	55000
Soil surface treatment with herbicide	kg	10000	1	10000
Organic fertilizer/manure		20	25000	50000
Fertilization with manure	ha	20000	1	20000
Herbicide	kg	3500	2	7000
Sow	ha	20000	1	20000
Cultivation of inter-row spaces: 2 times	ha	15000	2	30000
Nitrogen fertilizer	kg	180	250	45000
Watering: 3 times	cubic meter	11	240	26400
Salary of the worker for irrigation	ha	10000	3	30000
Harvesting	ha	40000	1	40000
Transporting the yield	kg	6	5000	30000
Harvest filtering, canning	kg	10	2500	25000
Land tax	ha	23000	1	23000
Transportation and other expenses	-	-	-	30000
Total costs	-	-	-	**545400**

The cost-benefit analysis reveals that 1 ha of sorghum cultivation requires 545,400 AMD investment, while the expected revenue generated from the sale of the resulting grain may reach the level of 1,000,000 providing around 83.3% profit. In addition, 13t/ha of vegetative mass (stem leaves) is formed, each kg of which provides an energy value of 17.3 MJ in a form of briquette.

Additional revenue from the sale of biomass to briquetting sites will amount to 260,000 AMD if sold for the producers' suggested 20AMD/kg price.

Due to a lack of demand, grain sorghum is not very common in Armenia. Nevertheless, we suggest developing the grain sorghum that can be used to make dietary flour for food purposes, which has grown to be fairly important recently, as well as a high-quality component for the creation of concentrated and mixed feed, which is in high demand in the Yeghvard feed manufacturing hub. A useful raw material for briquetting can be found in the remaining vegetative mass of grain sorghum, given its high energy content. This crop may be grown in all agro-climatic zones, especially in arid conditions, and is highly climate change adaptable due to its drought tolerance.

3.4 Jerusalem Artichoke

Jerusalem Artichoke is a perennial crop of the Asteraceae family, with food, fodder and technical significance. Currently, there are no significantly large agricultural fields of production in Armenia. Due to the biological characteristics of the crop, it is possible to cultivate in all agricultural zones. In arid zones, it is mainly cultivated under irrigated conditions, while in regions with relatively high rainfall and temperate climates, it is cultivated under dry conditions. In RA, it is possible to cultivate in agro-climatic zones with an altitude of 500-2200m above sea level, in all regions. The best results are provided in regions with relatively cool and temperate climates, particularly in the medium-altitude areas of Kotayk, Lori, Gegharkunik and Shirak regions. The height of the stems of the plant is 2-4 meters. In the soil, at the base of the stem, it produces tubers of different colors and shapes. The lack of productive plantings in Armenia is mainly due to the scarcity of a large quantity and quality of planting material-tubers, as well as the limited possibilities of sustainable sales of complete products (tubers, stems and leaves) obtained from the crop.

Application

The tubers are used as food and fodder. Alcohol and fructose are obtained from the tuber. For food purposes, the tubers are used fresh or processed. Canned juicy fodder - silage - is prepared from the above ground green mass. The maximum content of inulin polysaccharide in stems is 2-4%, leaves do not contain inulin, the maximum content of inulin polysaccharide (polysaccharide) in tubers is 14-22%. In case of tuber cultivation, harvesting of the above-ground vegetative mass produces a huge bulk biomass: stems and leaves are rich in membrane, which in the dry state can be the best feedstock as fuel biomass because of its high energy value, each kilogram provides 17.03 MJ of energy.

Cultivation technology and conditions

Jerusalem Artichoke grow well in all agricultural zones, since it is not demanding on the soil. Except for extremely salinized, acidic, and swampy soils, it grows and develops normally in all other soil types. Since Jerusalem Artichoke reseeds in the same field over a number of years, it is good to include it in crop rotations for fodder. For tuber production purposes, it is typically grown in wide rows method with plants spaced 25–30 cm apart and rows 60–70 cm distance. Vegetative breeding is provided by the tuber planting. When preparing the soil for cultivation, deep plowing should be done in the autumn before planting. During this time, the primary mineral (PK) and organic manure fertilizers are applied to the soil. Before sowing, raking is done as soon as the field is accessible in the spring, then 1-2 times cultivation (depending on the weediness of the field) and machine planting followed. Tubers weighing 30-50g are used as planting material, at the rate of 1.7-2.5 t/ha.

It is feasible to plant the Jerusalem Artichoke tubers in the fall as well because of its tolerance to winter temperatures. For tuber production purposes, typically seeding are planted in wide rows with plants spaced 25–30cm apart and rows in 60–70cm distance. Tubers are harvested as needed: in fall, late fall, and spring, while green mass harvesting of Jerusalem Artichoke for silage should be done during the massive flowering stage of the plants. The yield of tubers is up to 25-30t/ha, while the green mass of above-ground stems and leaves provides a yield of 50-80t/ha. The massive above-ground coarse and film-rich biomass that is removed prior to the harvest of tubers can be used as a source of energy, especially for the production of biofuel, due to its high energy content, with each kilogram delivering 17.03 MJ of energy.

The technical indicators of the crop are summarized in the table below.

Table 6: Technical indicators of Jerusalem Artichoke and its technological card

Crop	Duration of vegetation	Dry vegetative mass	Irrigation and heat requirements	Energy value of biomass, MJ/kg	Briquetting potential
Jerusalem Artichoke	90 -140 days	10000/ha	It is moisture-loving. Salt tolerant, does not grows well in swampy and acidic soils	17.03MJ/kg	~ 8.3t/ha

Materials or activities	Unit	Unit Cost	Quantity (kg, ha, cubic meter)	Total Cost, AMD
Seed	kg	220	2300	506000
Fertilization from the field: Phosphorous	kg	200	280	56000
Fertilization from the field: Potassium	kg	250	280	70000
Tillage: main tillage, leveling	ha	55000	1	55000
Soil surface treatment with herbicide	kg	10000	1	10000
Organic fertilizer/manure	ha	20	25000	50000
Fertilization with manure	ha	20000	1	20000
Herbicide	kg	3500	2	7000
Planting	ha	25000	1	25000
Cultivation of inter-row spaces: 2 times	ha	15000	2	30000
Nitrogen fertilizer	kg	180	200	36000
Watering: 3 times	cubic meter	11	2400	26400
Salary of the worker for irrigation	ha	10000	3	30000
Harvesting	ha	25000	1	25000
Transporting the yield	kg	5000	30	150000
Land tax	ha	23000	1	23000

Transportation and other expenses	-	-	-	30000
Total costs	-	-	-	1149400

The cost-benefit analysis reveals that 1ha of Jerusalem Artichoke cultivation requires 1,149,400 AMD investment, while the sale of the harvested tuber may generate around 1,650,000AMD revenue, providing approximately 43.5% profit. In addition, about 10t/ha of vegetative dry mass (stem, leaves) is formed, each kg of which may provide up to 17.03 MJ of energy value in briquetting form. Additional revenue from the sale of biomass to briquetting sites will amount to 200,000 AMD if sold for 20AMD/kg price suggested by the producers.

Currently, the vegetative residual mass of the crops has various applications. It can be used as a coarse bulk feed in case of Poaceae crops, animal bedding, in field farming as a mulch. In the case of some crops, such as maize, sunflower, grain sorghum, during mechanized harvesting to get grain and seed, the vegetative mass, ground stems and leaves, is spread over the field and mulched to serve as organic matter to improve soil nutrition and physical condition. This is an accepted practice in the world, and in Armenia it is partially implemented in the fields cultivated for obtaining grain under the conditions of the Ararat Valley (also due to the availability of technical means). Any crop residue, as an organic compound, contributes to improving the quality of the soil and enriching it with nutrients. It is mainly carried out as a technology during sideration or if the residual biomass does not pursue other purposes of use. In the scientific literature, crop residue is considered as a means of fertilization only during sideration. In general, during targeted fertilization, the crop resides are not used as such, but is turned into fertilizer by composting and is only introduced into the soil, so that the processes of decay and decomposition are accelerated and the nutrients available to the plant in the soil are more quickly absorbed into the soil. In some cases, the elimination of residual biomass can even have a negative impact on the environment, such as straw burning. Vegetative residues of maize and sunflower are also used as bulk fodder in a ground state. In case of sunflower, after separating the seed, the residual biomass of the pod is used as a good quality feed.

Table 7: Summary characteristics of selected crops

Crop	Elevation above sea level for cultivation	Vegetation period (days)	Growth in degraded soils	Availability of seeds/seedlings in Armenia	Availability of fields for cultivation	Preferred regions
Maize	500-2000m	90-140	Poor	Imported from abroad/no local seed production	Available	Ararat, Armavir, Aragatsotn, Kotayk, Gegharkunik, Lori, Tavush, Syunik, Shirak
Sunflower	400-2000m	90-140	Moderate	Imported from abroad/no local seed production	Available	Ararat, Armavir, Aragatsotn, Kotayk, Gegharkunik, Lori, Tavush, Syunik, Shirak
Sorghum	400-1800m	90-145	Moderate	Imported from abroad/no local seed production	Available	Ararat, Armavir, Aragatsotn, Kotayk, Gegharkunik, Lori, Tavush, Syunik, Shirak
Jerusalem artichoke	500-2200m	90-170	Good	Imported from abroad/no local seed production	Available	Aragatsotn, Kotayk, Gegharkunik, Lori, Tavush, Syunik, Shirak

Table 8. Yield, financial feasibility, dry biomass and energy value of selected crops

Crop	Dry vegetative mass	Irrigation and heat requirements	Energy value of biomass	Briquetting potential	The revenue generated from the sale of the product from 1 ha (main product + biomass)
Maize	15000-16000 kg/ha	500-800m^3/ha heat-loving plant	16.7 MJ/kg	~14 t/ha	1710000 AMD
Sunflower	10000-12000kg/ha	300m^3/ha, heat-loving plan, 18-26 °C	16.8 MJ/kg	~9.9 t/ha	1120000 AMD
Sorghum	13000 kg/ha	Heat-loving, drought resistant, salt tolerant	17.3 MJ/kg	~ 11 t/ha	1260000 AMD
Jerusalem artichoke	10000kg/ha	Moisture-loving, salt tolerant, does not grow well in swampy and acidic soils	17.03 MJ/kg	~ 8.3 t/ha	1850000 AMD

4.THE CONCEPT OF THE PILOT PROJECT

According to the characteristics of the selected crops and technology cards, a pilot concept note has been developed, the details of which are given below.

4.1 Selected Regions

The implementation of pilot operations is suggested in five different regions of the Republic of Armenia, namely Aragatsotn, Kotayk, Shirak, Lori, and Tavush (refer to Table 8 for details).

Table 8: Regions, Localities, and Implementation Conditions of Pilot Operations

No	Region (Marz)	Area	Settlements	Conditions of cultivation	Area of Cultivation (ha)
1	Aragatsotn	Ashtarak	Agarak, Sasunik	Irrigating	4
2	Kotayk	Eghvard	Zoravan, Aragyugh	Irrigating	4
3	Shirak	Gyumri	Akhuryan, Horom, Azatan	Irrigating	4
4	Lori	Vanadzor	Shahumyan, Gugark, Vahagni	Irrigating	4
5	Tavush	Berd	Varagavan, Verin, Tsaghkavan	No Irrigation	4

The selection of these regions and settlements for the pilot operations is based on various factors. Firstly, it considers the presence of suitable bioclimatic conditions necessary for the healthy growth of the selected four crops. Secondly, regional demand for primary and main crop products is taken into account, focusing on their intended purpose, whether for food or fodder. Furthermore, the selection also considers the potential for on-site utilization of emerging agricultural residues and vegetative biomass. This includes exploring possibilities to utilize biomass as a feedstock for briquetting (and pelletizing) production units operating within the region. ANAU expert team has contacted briquetting units to get informed about their readiness to be part of the pilot. Most of the units have expressed their strong interest to be part of the project. Their concern is whether the residues of the selected crops can bear the desired results in terms of the final products. However, this is also one of the objectives of the pilot to experiment with new types of residues and check their actual feasibility. Ensuring a stable supply of such biomass is of utmost importance in these areas.

The preliminary data on the relevant briquetting points for the pilot project is presented below.

Table 9: List of the briquetting units

Production place, beginning of activity and product type	Ownership and management	The total volume of products produced so far	Expected feedstock demand from proposed crops	Available Technical capacity to engage in pilot operation
Shirak region of RA, Basen community, 2016 NESTRO Briquettes	Basen Community Development Fund	The main raw material is grass, 50-55 tons	It depends on the actual results of the pilot being carried out	Available
Shirak region of RA, Basen community, 2016 NESTRO Briquettes	Caritas Benevolent NGO	Up to 1 ton/per day (annual data not available yet)	It depends on the actual results of the pilot being carried out	Partially available
RA Lori region, Mets Parni community, 2018 NESTRO briquettes	"METS PARNI" Climate Civil Revolving Investment Fund	The main raw material is pruned branch biomass in the Ararat Valley, 550- 600 tons	It depends on the actual results of the pilot being carried out	Available
RA Tavush region, Varagavan community, Piny Kay briquettes	Armen Abrahamyan Private Entrepreneur	The main raw material is the remnants of vineyards, 180-200 tons of straw wood material	It depends on the actual results of the pilot being carried out	Available
RA Kotayk region, Zoravan community, NESTRO briquettes	Eco Range LLC	The main raw material is straw, 900-1100 tons	It depends on the actual results of the pilot being carried out	Available, among the selected crops sunflower and Jerusalem artichoke have been successfully tested
RA Lori region, Vanadzor Piny Kay briquettes	Eco varm LLC	The main raw material is wood waste, about 1000 tons	It depends on the actual results of the pilot being carried out	Not available, technical refurbishment is possible

4.2 Mechanism of Implementation

To implement the pilot operations successfully, we suggest cultivating each of the four selected crops in the target settlements across the five chosen marzes. A cultivation area of 1 hectare will be organized for each crop in each suggested location. This area may consist of private or community owned arable land, offering flexibility in the selection process. The main beneficiaries shall be various stakeholders engaged in agricultural activities. This encompasses households involved in farming, private farms with legal entity status, local self-governing bodies, agricultural cooperatives, and organizations operating in the region that specialize in solid fuel production from vegetable biomass raw materials. The aim of involving diverse stakeholders is to create a collaborative and inclusive approach towards sustainable agricultural practices and the utilization of vegetable biomass resources for solid fuel production. This can not only promote economic growth but also contribute to the overall development and well-being of the target settlements in the selected marzes.

It is suggested to accompany the pilot implementation with workshops and demonstrations for knowledge sharing and capacity development of relevant stakeholders. These activities will enhance their knowledge and skills related to crop production, residual biomass processing and financial literacy. During the piloting regular feedback and input from stakeholders will be collected. This can ensure continuous improvement as well as identification of challenges in a timely manner and addressing them accordingly.

4.3 Actions and Schedule

It is suggested to implement pilot activities in two distinct phases. As the selected crops are heat-loving spring species, the sowing of crops in various regions should take place during the spring period of the year following the main preparation of arable land. This preparation, involving tillage and organic fertilization, will be conducted in the late summer and autumn of the year preceding the crop rotation, considering the specific climatic conditions of each region. Additionally, the necessary amount of seeds for sowing will be acquired during the same period, and short-term contracts or agreements will be concluded with the owners of the selected arable land (private entrepreneurs, municipal local governing bodies) as well as with the briquetting production units responsible for procuring the residual vegetative biomass.

Phase No.1 entails the selection of suitable arable land for cultivation, establishing contractual relationships with beneficiaries, managing the selected arable land, and implementing basic (organic) fertilization works for crops. The purchase of the required amount of fertilizers for basic fertilization and nutrition, along with the necessary quantity of seeds corresponding to the different crop types, will also take place during this phase.

Phase No. 2 focuses on the pre-sowing cultivation of the soil, the actual sowing of crops using the acquired seed material, the organization of care and harvesting essential for the crops, and arranging for the procurement of the residual biomass from the crops. This biomass will serve as raw material for production of solid fuel by specialized organizations. By implementing these phases systematically and efficiently, the aim is to ensure a successful crop cultivation process and the sustainable utilization of agricultural residues, contributing to both economic growth and environmental conservation.

Activities to be performed in the year preceding the sowing of crops	
July – August	Selection of arable land for pilot implementation in communities of selected regions
July – August	Setting contracts or agreements with arable land owners - individuals, legal entities or local self-government bodies
August - September	Basic tillage of the soil: deep tilling (28-30 cm) and organic fertilization at the same time

October - November	Acquisition of necessary mineral fertilizers for the fertilization of seeds and emerging crops of the proposed crops
Activities to be performed in the crop sowing year	
April – May	Pre-sowing soil cultivation: raking, cultivations
April – May	Sowing crops, fertilizing
May June	Implementation of mineral nutrition of crops
May – August	Crop care activities: inter-row loosening, irrigation, fertilizing
August - October	Organization of harvesting, sorting. Delivery of residual biomass to procurement organizations (briquetting units).

4.4 Financial Considerations

The main part of the activities carried out during the implementation of the project refers to the cultivation of crops in accordance with the requirements of the technology card drawn up for each crop. The cards show the necessary measures to carry out sound cultivation, and the average values of measures, materials and supplies for possible financial investments are presented (see Chapter 2: Characteristics of selected crops). According to the total investment costs calculated from the crop cultivation technology cards, the total project budget was derived. The planned measures and financial investments for the cultivation of 4 different crops for a conventional 1 ha area are presented in tables. The total costs required for the 4 ha of irrigated area for the cultivation of 4 types of crops at the level of each selected region will be around 2,975,200 AMD, and for the 4 ha of waterless area it will be around 2,674,400 AMD (see table 10)

Table 10: Financial Investments for the Pilot

	Crop	Area (ha)	Required Investments (AMD)	
			Irrigating Conditions	Non-Irrigating Conditions
1	Maize	1	677,800	565,000
2	Sunflower	1	602,600	527,400
3	Sorghum	1	545,400	489,000
4	Jerusalem Artichoke	1	1,149,400	1,093,000
	Total	**4**	2,975,200	2,674,400

It is suggested to implement pilot projects in irrigated conditions of 4 marzes (Aragatsotn, Kotayk, Shirak, Lori) and in non-irrigated conditions of 1 marz (Tavush) on a total area of about 20 hectares, therefore the total investment of the project for the cultivation of crops will be:

4 X 2,975,200 + 1 X 2,674,400 = 14,575,200 AMD

The success of the suggested pilot projects will be primarily determined by evaluating the quantity of main and by-products from crop production, the selling price of unit products (per 1 kg), and the production cost. To assess its economic viability, a cost-benefit analysis was conducted to consider the average market sales prices of primary crop products and estimates the expected efficiency (profitability) of both main and by-products (additional biological mass) vegetable products. This comprehensive analysis combines expenses incurred and income generated from product sales, as outlined in Table 11.

The calculated average data obtained from this analysis provides a clear understanding of the project's validity and efficiency concerning the cultivation of the selected four crop types. This assessment considers not only the primary plant products but also the residual biomass produced and utilized for energy purposes. Encouragingly, all investigated options demonstrate high profitability, validating the project's potential to yield positive economic outcomes.

Table 11: Economic efficiency of cultivation of crops per 1 ha area

Crop	Cultivating cost per ha, AMD	The product yield from 1ha, kg		The market price of the product per kg, AMD		The revenue generated from the sale of the product from 1 ha, AMD			Profita-bility %
		Main	By-Products	Main	By-Products	Main	By-Products	Main + By-Products	
Maize	677,800	4,000	15,500	350	20	1,400,000	310,000	1,032,000	152,2
Sunflower	602,600	2,000	11,000	450	20	900,000	220,000	517,000	85,8
Sorghum	545,400	5,000	13,000	200	20	1,000,000	260,000	714,000	131,0
Jerusalem Artichoke	1,149,400	30,000	10,000	55	20	1,650,000	200,000	700,000	60,9

The selection of the pilot regions also took into account the presence of production units specialized in the production of solid fuel from vegetable raw materials in the regions, to ensure the full feasibility of the production of solid fuel from vegetative residual biomass in the value chain, apart from the primary crop products, at the regional level. The economic justification for the value chain of solid biomass fuel production by processing vegetative biomass as an auxiliary crop product formed as a result of crop cultivation on a conventional 1 ha area was calculated (Table 12).

Table 12: Economic evaluation of solid biomass fuel production from vegetative biomass per 1 ton of raw material (considering the crop cultivation within 15 km distance)

Raw Materials	Purchasing price including transport costs, AMD	Production costs of processing 1 ton of biomass, AMD	The cost of 1 ton of energy product (briquette), AMD	Selling price of the energy product (briquette), AMD	Net Profit	Profitability %
Vegetative biomass residues of the field crop	30,000	35,000	65,000	110,000	45,000	69,2

4.5. Risk Managmenet and Mitigation Plan

A risk management and mitigation program is paramount to field crop production, given the unpredictability of weather, pest and disease outbreaks, market fluctuations, and other factors. A structured risk management and mitigation plan should help the pilot program identify potential risks and vulnerabilities from yield to liquidity.

The risk management and mitigation plan presented below addressed the procurement of resources such as seeds, fertilizers and farm machinery, technological risks, and cultivation challenges.

Potential Risks to the pilot	Description	Likelihood Level	Consequence	Response to Activities
Cultivation challenges	The risks associated to adverse weather conditions, pest or disease outbreaks, or suboptimal cultivation practices.	2	This event will severely impact the pilot project such as complete failure, significant financial distress. The pilot team might require substantial intervention or restructuring of the planned activities to address the aftermath of crop failure.	• Cultivation of all 4 selected crop species to mitigate the risk of pilot implementation in case of complete failure of one crop • Continuously monitor the weather forecast to implement respective measure such as irrigation or protective structure • Develop pest and disease management plans, including early detection, monitoring, and interventions.
Resource Restraints	This risk is associated with inadequate availability or access to essential resources including but not limited to arable areas, seeds, water, fertilizers, or agricultural machinery	2	In case of this risk, the pilot might face significant delays, increased costs, or reduced yields. The pilot team will need to put additional efforts and resources to recover and mitigate the impact.	• Plan carefully before the pilot initiation: pinpoint the potential sources of resource procurement, collection, and logistics. • Establish contractual relations with resource owners and coordinate with support institutions to facilitate the • Define the strategy of resource use, allocation, as well as plan alternative sources, or optimize resource usage. • Collaborate with other stakeholders to access additional resources if needed.
Technological Risks	This type of risks is mainly attributed to the processing of agricultural residues for solid fuel.	4	The pilot may suffer financial losses and may not achieve its main goal. The pilot team should review the selected briquetting production units depending on their technological resource availability. When commencing a pilot intervention, establish contractual relations for procurement and processing of raw biomass.	• Regularly monitor and evaluate technical operations with the briquetting units. • Make a reserve list of briquetting units, that will be ready to cooperate/valorize the residues. • Closely collaborate with agricultural experts or consultants to address technical difficulties and optimize processing. • Prior to the start of the pilot operation, scrutinize the considered briquetting units to assess their technical feasibility to be involved in the pilot operation.

5. CONCLUSIONS

The proposed pilot project involves the cultivation of Maize, Sunflower, Jerusalem Artichoke, and Sorghum in five different regions of Armenia. It can play a significant role in substantiating several essential arguments:

- **Exploring crop cultivation possibilities in varying agro-climatic conditions:** The pilot project will assess the appropriateness of crop cultivation in different climatic zones of Armenia, considering factors such as temperature, soil type, and water availability.
- **Identifying new production opportunities:** Apart from primary crop production, the pilot will explore the use of residual biomass for feed and energy purposes. This aims to establish new production value chains, especially in solid biomass fuel production.
- **Justifying economic and technical viability for energy purposes:** The pilot project will determine the feasibility of using residual biomass to produce solid biofuel from both technical and economic perspectives. This will include assessing the volume of residual biomass, processing capabilities, and required financial investments, providing more accurate and experience-based estimates of overall crop profitability in each region.

The results of the pilot program are expected to have a positive impact on Armenia's agriculture and energy sectors. By demonstrating the feasibility of crop cultivation and its potential to create new production opportunities, the initiative can promote sustainable agricultural practices and help address the country's food and energy security challenges. Additionally, utilizing residual biomass for energy purposes can foster the development of renewable energy sources, reducing Armenia's dependence on fossil fuels and promoting environmental protection and sustainability. The active involvement of communities, farmers, solid biofuel companies, and other stakeholders is essential to ensure the success of the pilot project. Close cooperation with research institutions and field experts will further contribute to achieving favorable outcomes.

In conclusion, the successful implementation of the pilot project can not only highlight the importance of the food and feed value of the four selected field crops but also underscore their energy value as additional raw materials in prospective biofuel production.

6. REFERENCES

1. Bhagia, Samarthya, et al. "Biofuel production from Jerusalem artichoke tuber inulins: a review." Biofuel Research Journal 4.2 (2017).
2. Debaeke, P., Bedoussac, L., Bonnet, C., Mestries, E., Seassau, C., Gavaland, A.& Justes, E. (2017). Sunflower crop: environmental-friendly and agroecological. OCL Oilseeds and fats crops and lipids, 23(4), 12-p.
3. A. Pasoyan, Nune Sakanyan (2020). Energy demand, supply and efficiency in rural Armenia: baseline data collection and analysis
4. Fayvush, G., A. Aleksanyan, and H. Hovhannisyan. "Aggressive plants. The most important invasive and expanding plants of Armenia." (2020).
5. Ivanova, Tatiana, Alexandru Muntean, and Petr Hutla. "Quality assessment of solid biofuel made of sweet sorghum biomass." BIO Web of Conferences. Vol. 10. EDP Sciences, 2018.
6. Jakubowski, Marcin. "Cultivation potential and uses of Paulownia wood: A review." Forests 13.5 (2022): 668.
7. Morgane Gillard (2020): Paulownia: Invasive or Not?
8. Parveen, Mobina, and Jagatpati Tah. "Studies on the yield components of Amaranthus sp in tropical plains of West Bengal (India)."
9. Paulowniabg: https://paulowniabg.info/?page_id=191 (Accessed: May, 2023)
10. Plantvillage: https://plantvillage.psu.edu/topics/sorghum/infos (Accessed: May, 2023)
11. Sitkey, Vladimír, et al. "Biogas production from amaranth biomass." Acta regionalia et environmentalica 10.2 (2013): 59-62.
12. Skoufogianni, Elpiniki, et al. "Maize as energy Crop." Maize-Production and Use. London, UK: IntechOpen, 2019.
13. Statistical Yearbook of Armenia Report, 2022
14. UNDP 2020: Sustainable Development of Biomass for Heating in Armenia
15. UN FAO: https://agris.fao.org/agris-search/search.do?recordID=SK2013000037
16. USDA Planting and Managing Giant Miscanthus as a Biomass Energy Crop 2011
17. USDA:https://www.fs.usda.gov/database/feis/plants/tree/pautom/all.html (Accessed: May, 2023)
18. Virani, Tasneem. The economic feasibility of bioenergy production from Miscanthus for the Ontario greenhouse industry. Diss. University of Guelph, 2011.
19. Wikifarmer.https://wikifarmer.com/sunflower-history-uses-and-plant-information/
20. Wood Pellet Mill: https://www.wood-pellet-mill.com/Solution/sunflower-pellets.html (Accessed: May, 2023)
21. World Tree: https://www.worldtree.eco/is-the-empress-paulownia-tree-invasive/

(Accessed: May, 2023)

7. APPENDICES

Appendix 1. Main activities carried out in different stages of the study

REPORT	MAJOR TASKS DESCRIPTIONS
INTERIM REPORT N1	Reviewed and summarized the recent five-year published official and available informal data and information about the quantities of agricultural postharvest residuals (biomass) and other potential sources to serve as suitable raw material for alternative biomass fuel (cereals, vegetables, pruned tree residues, etc)
INTERIM REPORT N2	Reviewed the relevant literature, international and local projects reports and practical experience to identify potential local agricultural crops, which may serve both for agricultural/fodder and energy crops purposes. The cases of Paulovnia, Miscanthus, Amaranth and Quinoa as energy crops were explored.
INTERIM REPORT N3	The most perspective 4 species were identified with cost-benefit analysis (inputs and outputs) justifying financial/economic feasibility.
INTERIM REPORT N4	Detailed piloting concept for the most perspective 4 species was developed for cultivating in different marzes.

Appendix 2. The list of interviewed experts

Area Of Expertise	Full name of the expert	Organization
Environmental Protection	1. Alen Amirkhanyan 2. Artur Ghavalyan 3. Samvel Tamoyan	Acopian Center for the Environment Ministry of Environment ANAU
Economic and Social aspects	1 Vardan Torchyan	ADA
Broad Expertise	1. Astghik Danielyan 2. Karen Minasyan 3. Lusine Tadevosyan 4. Gagik Palyan 5. Suren Davtyan 6. Hamlet Petrosyan 7. Gevorg Petrosyan 8. Khachatryan Gor	1. UNDP 2. Private Sector 3. ICARE 4. Private Sector 5. Private Sector 6. Private Sector 7. Private Sector 8. Private Sector

Appendix 3. Other studied crops: Paulownia, Miscanthus, Quinoa and Amaranth

Paulownia

Biomass from paulownia processing can be utilized to make briquettes and pellets for alternative energy. In the commercial sector, high-quality stumps (the stem without branches) are typically used for high-quality furniture production, while the remainder of the biomass, such as shoots, sawdust, and dried leaves, can be used as feedstock for pelletizing, briquetting, biogas, and bioethanol. The calorific value of solid fuels derived from paulownia biomass is high. Although there is scientific controversy about the efficacy of paulownia pellets and briquettes, several research has demonstrated that briquettes and pellets generated from P. tomentosa and P. elongata branches produce satisfactory energy results. It is worth noting that the energy value of paulownia is comparable to the energy value of widely cultivated tree species like willow and poplar.

Paulownia tomentosa has been designated as invasive by the US Department of Agriculture. However, the cross-breeding of Paulownia elongata and Paulownia fortunei, which World Tree planted in the Americas, is not deemed invasive. According to several scientists, the outward physical similarity of Pavlovnia species causes many farmers to be concerned about their invasiveness. In fact, most material on the genus Paulownia applies to Paulownia tomentosa, therefore generalization often leads to confusion about the invasiveness status of all other species. Also, a sterile hybrid of "elongata" and "fortunei," two Pavlovnia species, has been developed, which, according to the Valencian government, is a significant contribution to crop genetic development that does not represent a risk of displacement and "colonization" of local flora.

According to the book "Invader plants - The most significant invasive and expansive plant species of Armenia," (authors: Faivush G.M., Aleksanyan A.S., Hovhannisyan H.I.), published in 2020 by the Institute of Botany named after A.L. Takhtajyan, Paulownia species was discovered for the first time in Armenia in 2008 in Koghb village of Tavush marz. It was discovered about 900 meters above sea level. It is unclear if it was done on design or by chance. This tree has yet to bear fruit. There are currently 16 paulownia sterile hybrid seedlings on the market, all of which are non-invasive. It should be mentioned that controlling and evaluating the accuracy of sterile seedlings on the market is currently quite difficult. According to the mentioned publication (p. 80), this species can currently be used with little risk in Armenia's non-forest regions (Shirak, Armavir, Ararat regions). It has not been yet seen in any of Armenia's specially protected natural areas. Nonetheless, paulownia has been identified as a potentially invasive tree species.

In a media interview, the paleontologist Gabrielyan stated, "It is an invasive plant in many areas, and if it 'feels good,' it will suppress the native species historically established in that area, and if it brings any pests with it, it will cause more damage to other tree species, especially wild ones" (Aliq Media, July 30, 2021). It is worth noting that this interview discusses Paulownia tomentosa, which has already been confirmed as invasive in several US states.

In a notification released on July 29, 2021, the Ministry of Environment asked individuals to refrain from mass cultivation of Paulownia trees, particularly in Lori, Tavush, and Syunik regions (due to humid climatic conditions), until "circumstances connected to invasiveness analysis are addressed." In conclusion, Paulownia tomentosa is a potentially invasive tree, although the findings of experimental investigations on other species are still lacking. Furthermore, it is unknown how other Paulownia species would do in Armenia, even if they are not invasive. A comprehensive clarification of this subject still necessitates much experimental scientific research.

Miscanthus

Miscanthus is a plant that has received little attention, and information about its genetics and cultivars can be discovered in foreign publications.

Miscanthus can grow in a wide range of climatic conditions, however, there are certain characteristics that are essential for better growth of Miscanthus: the available sunshine in the area, the amount of rainfall, and the temperature (Caslin, Finnan, and McCracken 2010). According to bibliometric examination of the literature, high biomass of Miscanthus can be achieved at temperatures ranging from 28 to 32°C. Miscanthus growth slows at 6°C. According to the literature, the growing conditions of Miscanthus are quite similar to corn, and because of these characteristics, Miscanthus can be cultivated in the irrigated areas of the Ararat Valley and foothills, though it can also be cultivated without irrigation in the mountain meadow-steppe and post-forest zones up to 2000m elevation.

The ability of the miscanthus to grow in partially deteriorated soils is one of the plant's valuable characteristics. However, excessive water retention in the soil in winter or early spring must be avoided since high moisture content might influence plant growth, development, and biomass productivity. Miscanthus should not be grown in locations with annual rainfall less than 500-600 mm.

Preliminary SWOT analysis for Miscanthus as an Energy Crop (prepared by the ANAU expert team based on the literature data):

	Success Factors	**Failure Factors**
Internal Factors	**Strengths** • A potential source of renewable and clean energy • High potential for the carbon sequestration • Climate change mitigation • Developing the rural biomass sector • Enriching the soil with Nitrogen • Soil nutrient efficiency • Nitrogen Efficiency • Increased soil organic matter • Minimum use of herbicides	**Weaknesses** • Sensitivity for water availability • High yield variability • Highly variable stand longevity • Considerable fire risk • Not widely available planting material • Limited climate adaptability • Land use competition
External Factor	**Opportunities** • Bio-rational use of marginal lands • Boosted local employment • New source of economic activities • Developing the rural biomass sector • Climate change mitigation	**Threats** • Risks of cultivation for fartmers • Lower local acceptance by farmers • Unwillingness of the consumers towards unknown plant • Legal regulations and administrative burdens towards introduction of the new plant • Underdeveloped biomass market

Weather and geographical location have a significant impact on miscanthus farming. There is no experience of miscanthus cultivation in the Republic of Armenia.

Quinoa

The "Seeds Agency" State Non-Commercial Organization assigned the responsibility of establishing Quinoa seeds production plots to various institutions as part of the TCP/RER/3802 project. These institutions include Gyumri Breeding Station in Shirak Region, private farmers in Martuni and Gavar towns in Gegharkunik Region, Vegetable and Technical Crops Scientific Center in Darakert, Ararat Region, and Agro Biological Technology Scientific Center in Edjimatsin, Armavir Region. The total area of the plots is 0.8 hectares.

The sowing process began in May 2021, with four different varieties of Quinoa seeds being planted: Kankolla, Inia 415 Pankalla, Incia 420 Negra Collana, and Blanca De Juli.

The results of the quinoa growth experiment show that the plant could be grown in Armenia, but it can be challenging. Due to the late seeding, the expert farmers claimed that the plants' seeds had not fully matured until October 2021. A smooth vegetation course, on the other hand, supplied acceptable plant height in all places, with robust stems and well-grown healthy leaves and flowers. Unfortunately, poor seed ripening was detected during the growth season.

The concerns and issues raised by experts, as documented in the previous Report from 2021 by the “Seed Agency”, are summarized below:

- Insects attacked the plants as soon as the green parts emerged. To address this in collaboration with the “Seeds Agency”, garlic water was used on the leaves.
- The growth process varies across different locations, resulting in differences in plant heights.
- Some farmers received only one type of seed.
- Certain farmers reported that irrigation was adequate, but the plants did not reach sufficient height development, and yet there were no seeds emerged.
- Some farmers reported good plant growth despite the fact that the vegetative process continued because the plants were sown in late spring 2021.

It is believed that the proper growth of quinoa in Armenia requires frequent and intensive irrigation.

Amaranth

Amaranth (Amaranthus L.) belongs to the Amaranthaceae family and is used for various purposes such as food, animal feed, decorative and technical purposes. The young stems and leaves of amaranth are used as leafy vegetables in cooking, the leaves of Amaranth contain a large amount of carotene and vitamin C. Flour from seeds is used in baking. For fodder purposes, green mass is mainly used in silage and as hay, as well as seeds as a component of concentrated fodder and combined fodder. It is a valuable forage plant rich in proteins. In cultivation, the tailed, bowed and shriveled types in the grain direction are especially popular. In irrigated warm agricultural zones, it can be mowed 2-3 times, providing high green mass up to 1000 c/ha yield. It is a heat-loving, drought-resistant crop that can be cultivated in the lowland, foothill, and post-forest zones of the country. To obtain green mass for fodder, the sum amount of active heat in the cultivation zone should be 1700-2000^{o}C, and for grain 1900-3000^{o}C.

Amaranth is relatively yield-sensitive to the soil, providing good growth and yield in nutrient-rich barren soils. Poor and low productivity is associated with the growth in acidic soils. It is cultivated in the usual row or wide-row manner. In order to obtain silage green mass, conventional row cultivation is recommended, and for obtaining grain, wide row (70 cm) cultivation should be assumed. The seeds of the crop are very small, the weight of 1000 seeds is 0.6-0.9 grams. Depending on the varietal characteristics, as well as the purpose of cultivation, the amaranth sowing rate is 0.5-2.0 kg/ha. In the irrigated arable lands of the lowland and middle zones, Amaranth provides up to 1000 centner of high-quality green mass, in which protein is more than 20% in terms of an absolute dry matter. For the silage mass, the plant is harvested at the development of the flowering stage. During the seeding and ripening stages of plants, the content of membrane material increases in the stems, due to which the feed value and nutrition of the vegetative mass decreases.

After the harvest of amaranth cultivated for obtaining seeds, the residual coarse vegetative mass does not have a high feed value and is used for fodder. For technical purposes, after harvesting the seed, the residual coarse vegetative mass can also be used as a raw material for production of energy briquettes.

UN FAO experts have identified amaranth as a plant that will help support our planet's ever-growing population with high-quality protein. Amaranth also has effective medicinal properties from the seed. The oil received from Amaranth has a high value among vegetable oils and animal fats. It contains the substance squalene used in the combined treatment of radiation sicknesses and is considered a potent antitumor agent.

Amaranth species with decorative significance are also common and are used for the purposes of landscaping and aesthetic designs in the urban economy. Large wild forms are also widespread, which are considered weeds, but have forage and high nutritional value.

Technical varieties of amaranth are currently cultivated in the city of Yerevan's greenhouse complex as decorative crops in the urban economy for aesthetic purposes in landscaping works, while various cultural varieties for the purpose of obtaining seeds (for oil production) were tested by a private entrepreneur under the conditions of the Balahovit Educational Experimental Center of ANAU, as well as in the arable land of Arai village of Aparan community. The testing produced favorable results. In general, amaranth cultivationwas carried out for fodder reasons in local areas in Armenia at the end of the last century, mainly in the Kotayk Marz.

The table below presents the summary information about the above species as well as the major obstacles for their cultivation.

Crop	Cultivation zones	Energy value of 1 Kg dry biomass	Major obstacles for cultivation
Paulownia	200-1300m above sea level	15 – 18 MJ/kg	Potentially invasive
Miscanthus	600 – 2000m above sea level	17.5 MJ/kg	High water requirements, no experience in Armenia
Amaranth	500 - 2000m above sea level	14.4 MJ.kg	Absence of the infrastructure for the major product, oil
Quinoa	500 – 1600m above sea level	18.27 MJ/kg	Currently experiments are going on, however, the results are not desirable

Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus (ECOserve)
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
59 Hanrapetutyan st., 9th floor
0010 Yerevan, Republic of Armenia

T +374 10 510065
I www.giz.de
http://biodivers-southcaucasus.org/

EU4Energy Efficiency
and Renewable Energy
in Armenian Communities