JIMDT, Vol. 6, 2024
RESEARCH ARTICLE
https://doi.org/10.5564/jimdt.v6i1.3598

Pastoral farming strategies and management adapted to climate change

Ariun-Erdene Dashjamts[1*], Uuganbayar Budjav [2*], Tseveengerel Tumurbaatar[1*]

[1] *Mongolian University of Science and Technology, 8th khoroo, Baga toiruu 34, Sukhbaatar district Ulaanbaatar, Mongolia 14191*

**Corresponding author: E-mail: daerdene@must.edu.mn; ORCID:0000-0002-6485-1045*

Article Info: Received: 2024.09.15; Accepted: 2024.10.01; Published: 2024.12.26

Abstract: Mongolia is one of the most sensitive and vulnerable countries to climate change, and the average air temperature has increased by 2.1℃ in the last 70 years. Also, the fact that climate change is negatively affecting not only natural ecosystems, but also major social and economic sectors such as agriculture, animal husbandry, and farming indicates the need for immediate and urgent measures. In this paper, the impact of adaptation opportunities to climate change is calculated by cost-benefit analysis, where and when it is appropriate to implement it was calculated by AHP method (Analytic Hierarchy Process), and social, economic and environmental effects are calculated by system dynamics modeling.
In this research work, it is possible to predict the results of adaptation measures to climate change using the method of dynamic system modeling on the example of Sukhbaatar Province, and the main feature is that the method of system dynamic modeling was used in combination with cost-benefit analysis and multi-factor analysis.

Key words: Climate change, pastoralism, experiment, simulation, System dynamics model.

1. Introduction

In order to fulfill its obligations under the United Nations Framework Convention on Climate Change, the Great Khural of Mongolia approved the "National Climate Change Program"in 2011. The program includes the goal of reducing the effects of climate change disasters on livestock, agriculture, water resources, and forestry, and contributing to the reduction of greenhouse gas emissions from industrial activities.

The main income of the rural people is based on meat and cashews, which is a factor in increasing the number of livestock. The increase in the number of livestock reduces the carrying capacity of pastures, and increases the vulnerability and vulnerability to climate change. There is global consensus that capacity building through adaptation measures is a key measure to reduce this vulnerability and risk.

Based on the concepts of ordinary differential equations, statistical theory, systems theory and system dynamics, the research will present the results of a model developed to demonstrate the effectiveness of pastoralist adaptation opportunities to climate change. The model can be used as a tool for long-term and medium-term overview of economic planning for adaptation to climate change, policy formulation, and management decision-making support.

Copyright © 2024 The Author(s). This is an open-access article distributed under the terms of the CC BY-NC 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/).

Copyright © 2024 The Author(s). This is an open-access article distributed under the terms of the CC BY-NC 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/).

From 1944 to 1980, the frequency of zud occurred once every 8-9 years, but since then, the frequency has become closer, and in 1999-2003, it did not miss a year. According to the research, the normal frequency of zud occurs once in 5.2 years [9]. Researchers L. Natsagdorj and J. Dulamsuren have made the repetition of "white"and "black"zud that occurred in Mongolia between the winter of 1972-1973 and 1999-2000. White zud is caused by lack of grazing due to heavy snowfall in the area, while black zud is caused by lack of snow it occurs mainly in the Gobi desert region [10] .

In our research, We used the World Bank's climate projections, specifically estimation of future trends in precipitation and average air temperature [12].

Climate change for Mongolia until 2050 will be 3-4 degrees Celsius, the annual amount of precipitation will be relatively stable and a slight increase, but the number of unexpected heavy rains will increase. We calculated 7 scenarios of global warming based on greenhouse gas emissions in our model and presented the best and worst case scenarios.
For Sukhbaatar province, the precipitation is about 300 mm, and the average air temperature will reach 2.5 celsius.

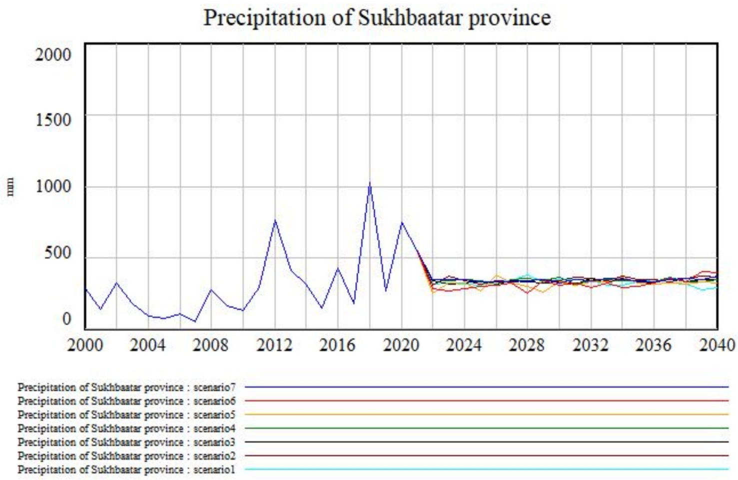


Figure 1: Precipitation of Sukhbaatar province.

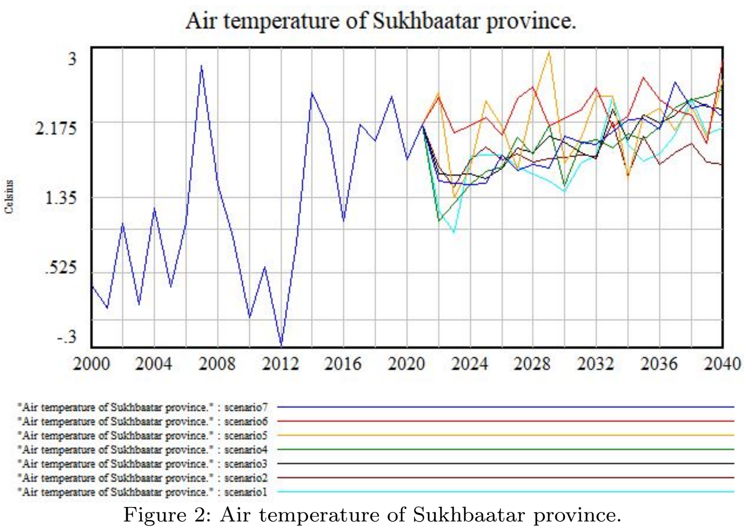


Figure 2: Air temperature of Sukhbaatar province.

At the province level, the risk will be high in 2023, 2033, 2036, 2038, 2039, and 2040 under scenario 1, and in 2024, 2026, 2030, 2035, 2036, 2038, and 2039 under scenario 7.

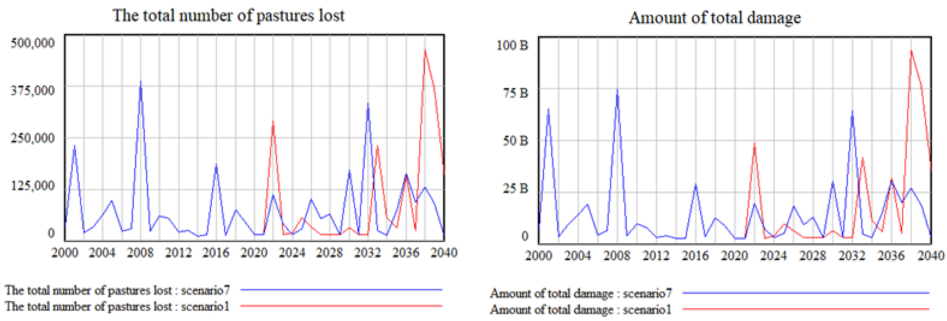


Figure 3: Total number of animals lost and total damage.

2. Survey methodology

The concept of systems dates back thousands of years, but scientific study began in 1948 when Norbert Wiener research paper published "Cybernetics or control and communication in Animal and the Machine".

In 1956, Ludwig von Verthalanffy formulated the science of systems science at the theoretical level in his book "General Theory of Systems". Since then, cybernetic concepts of the system have been studied more and since the 1980s, dynamic system states have been studied in detail.

The concept of system dynamics was first developed in the 1960s by the work of Jay Forrester and his colleagues at the Sloan School of Management at the Massachusetts Institute of Technology in the United States [5]. The methodology was initially used only in industry, but now it is successfully applied in all fields of organizational management, market growth, labor instability, public policy design, economics, environmental research, and science. [4]

D. Sterman defines system dynamics as "System dynamics is a set of tools that allows to understand the structure and seismicity (dynamics) of complex systems at the conceptual and principle level". D. Sterman calculated the global warming up to the year 2100 using the method of dynamic modeling of the system and showed mankind how the warming will change depending on the energy consumption.

Dynamic system models rely on three sources of information: numerical data, written databases (such as reports, user manuals), and industry expertise of key system participants. In this study, the system dynamic model was completed using the Vensim program. Vensim is a professional dynamic modeling program that calculates systems of ordinary differential equations with high precision numerical methods (Euler, Kunga-Kutta) at each time instant and displays the solution numerically and graphically.

The system dynamics model is characterized by a system of differential equations, We used the following fundamental equations. The logistic law with equation

$$\frac{dP}{dt} = r \cdot P \left(\frac{K - P}{K} \right)$$

was used to calculate the growth rate of livestock, and the 1212.mn website of the National Statistics Committee of Mongolia and the Statistical Bulletin of Mongolia /2000-2023/ were used as sources. Here: $\frac{dP}{dt}-$ Livestock population, $r-$Net growth rate, $K-$ Pasture carrying capacity, $P-$ Total grazing livestock number, converted to sheep head.

The Cobb-Douglas production function is used to model the production of economic sectors. For example, in the manufacturing sector, the volume of production and the number of employees working in the sector are selected as the main variables. The manufacturing sector production variable represents the annual value added of the manufacturing sector.To calculate this, the Cobb-Douglas production function is defined to conform to the following form:

$$Y = A \cdot K \cdot K^{(e-1)} \cdot L \cdot L^{-e}.$$

For example, the production of the manufacturing sector was taken in the following form.

$$P = P_{\text{initial}} * C_{\text{relative}}^{C_{\text{sensitivity}}} * E_{\text{relative}}^{(1-C_{\text{sensitivity}})} * P_{\text{impact}}.$$

Here: $P-$ Manufacturing Production, $P_{\text{initial}}-$ Initial Manufacturing Production, $C_{\text{relative}}-$ Relative Capital in Manufacturing sector, $C_{\text{sensitivity}}-$ Capital Sensitivity in Manufacturing sector, $E_{\text{relative}}-$ Relative Employment in Manufacturing sector, $P_{\text{impact}}-$ Productivity Impact on Manufacturing Production.

Cost-benefit analysis is a quantitative research tool that supports the decision-making process by estimating the benefits of a particular project or program, selecting the most cost-effective alternative among multiple alternatives, and implementing it. Cost-benefit analysis designed to evaluate adaptive measures and prioritize them.

It is necessary to determine the appropriate location of adaptation measures and to assess the level of importance, to identify multiple indicators, and to evaluate the actual values of those indicators appropriately. In the study, using the Analytic Hierarch Process (AHP) method, we created our own codes and calculated the weight of the criteria and calculated them using the following formula.

$$S_i = \sum X_i \cdot W_i$$

Here: X_i- criterion value, W_i- criterion weight value.

3. Climate change risk status

We developed a dynamic model of the system to study how climate change affects the Society, Economy, and Environment of Sukhbaatar Province. Figure shows the causal loop diagram between the factors estimated in the model.

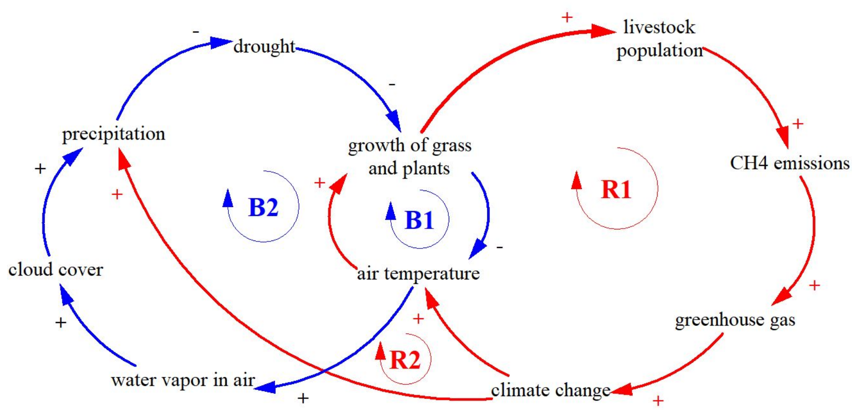


Figure 4: A casual loop diagram.

This article examines the implications for the livestock sector, outlines the future outlook for vulnerable risk situations, and shows how adaptation measures can mitigate risks. Most researchers believe that the potential carrying capacity of Mongolia's pastures is 74.3 million head of sheep per year.[6]

For Sukhbaatar province, calculated 3.81 million animals can be grazed by our model , but 7.19 million animals are grazing as of 2023, which indicates that the carrying capacity has been exceeded by 1.88 times.

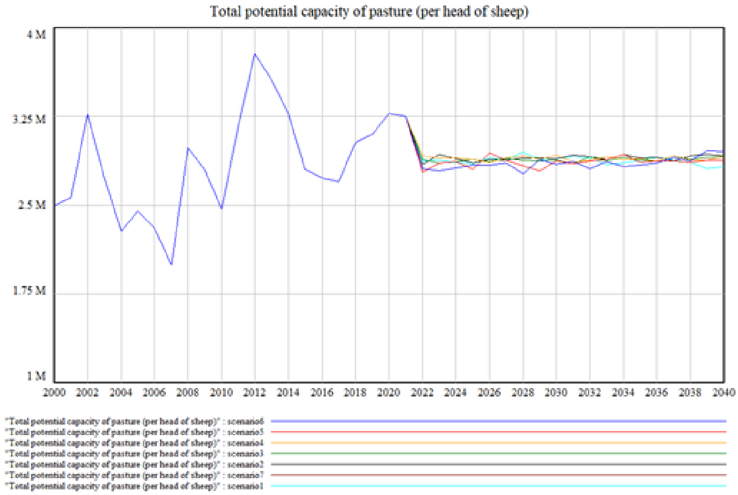


Figure 5: Potential grazing capacity.

If the climate change is normal, the gross domestic product of Sukhbaatar province would reach 1.75 trillion MNT in 2040, but it will decrease by 11 percent from the above level due to the climate change predicted by scenario 7 and by 20 percent by scenario 1. Also, the poverty rate is expected to increase by 17 percent in 2040, while it is expected to increase to 27 percent by Scenario 7 and 33 percent by Scenario 1.

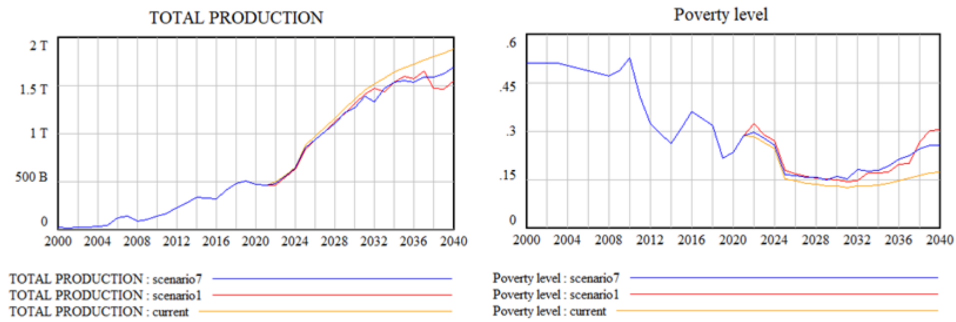


Figure 6: The Gross Domestic production and poverty rate.

The model estimates that the maximum amount of damage will reach 96.4 billion MNT in 2038 in scenario 1 and 69.1 billion MNT in 2032 in scenario 7 at today's market value.

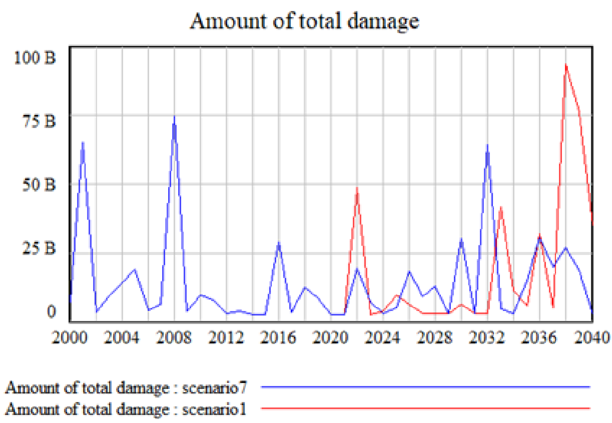


Figure 7: Total damage amount.

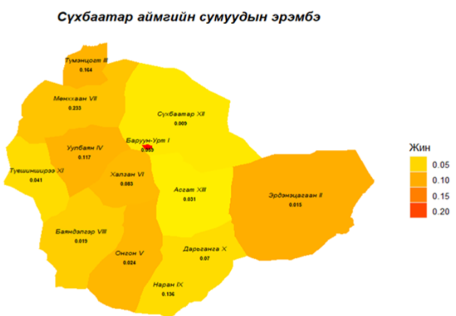
"Improving the ability to adapt to climate change and risk management of rural people in Mongolia project" work suggested that the following measures should be taken to develop pastoralism adapted to climate change.

- identify and strengthen the local breeds adapted to the local climate and forage, and create new breeds and races by hybridizing and improving the local breeds;
- introducing an insurance system to cover the loss of livestock;
- create a livestock early warning system to provide early warnings about the risk of catastrophic storms, droughts and fodder shortages;
- imparting skills, knowledge and information to adapt to climate change;
- teach and introduce agro-ecological technologies and practices of feed production and conservation to increase animal feed supply and nutrition;
- change the livestock management system or reduce the number of animals, increase productivity or profit from one animal, change the herd structure, improve animal health;
- improvement of pasture water supply or construction of engineered wells;
- bringing young animals into economic circulation [13], etc.

These climate change adaptation measures were incorporated into the system dynamic model and experimental simulations were conducted to find the optimal solution and predict the results.

4. Some results of adaptation measures

1. Reduce the number of animals and increase the value of raw materials of animal origin. Along with reducing the number of animals to meet the carrying capacity of pastures, it was considered very important to process and increase the value of animal-derived raw materials while not reducing the income of herding households. n terms of geographical location, Baruun-Urt, Erdenetsagaan, Tumentsogt, Uulbayan, Ongon, and Khalzan soums were considered the most suitable for the construction of factories and workshops for the processing of animal raw materials. Also, when calculated by AHP method, the above soums are ranked first. In determining this ranking, we considered the number of livestock, grazing capacity, labor force, and access to infrastructure.



Total rank		
Baruun-Urt	0.226	1
Erdenetsagaan	0.099	2
Tumentsogt	0.093	3
Uulbayan	0.093	4
Ongon	0.088	5
Khalzan	0.085	6
Munkhkhaan	0.073	7
Bayandelger	0.061	8
Naran	0.043	9
Dariganga	0.043	10
Tuvshinshiree	0.043	11
Sukhbaatar	0.029	12
Asgat	0.021	13

Figure 8: Ranking number soums of Sukhbaatar aimag.

Table 1: Plan for the construction of factories and workshops for the processing of animal raw materials.

№	Simulation version	Initial investment (billion MNT)	Annual Income (billion MNT)	Jobs to increase	Condition
a)	Meat processing plant	10.72	80	650	50 percent of the total livestock would be sent through the factory.
b)	by-product processing plant + meat processing plant	178.17	56.84	3480	50 percent of the animals to be sold would be sent through the factory.
c)	Dry milk factory and Airag factory	248.04	75	1891	50 percent of the milk would be sent through the factory.
d)	wool washing and combing factory	3.84	350	24	
e)	Primary leather processing plant	8.8	15	330	50 percent of the leather will be sent through the factory.

It is possible to increase productivity by semi-intensification of grazing animals and breeding with local hybrids. For this, it is necessary to first create and cultivate feed resources. There is a shortage of minerals/salt/, protein/rapeseed pulp/. For example, 460 tons of rapeseed pulp and 18 tons of salt are needed for semi-intensification of 1,000 cows.

2. Cost-benefit of putting young animals into economic circulation /lamb example/
The cost and profit of the measure "increasing the production of lamb meat, decreasing the number of wintering lamb and reducing pasture degradation" were calculated in four scenarios, which are herder household sells lamb by fattening on pastures and supplementary feed, or sell them after a year starting from 2025. **Cost**. The cost of an adaptation measure includes all additional costs incurred in initiating and implementing the measure. Therefore, the total cost is consists of 2 main parts

- Investment costs
- operational costs.

The investment cost wasn't calculated because the herder is selling the livestock at the household level. Operating expenses include the cost of salaries of the Herdsman, the cost of labor protection, the cost of additional feed and other costs. We only calculated the cost of additional feed.
Benefit. Benefit includes all the economic, environmental and social benefits of implementing the above measures.

- Economic
- Environmental
- Social
- climate change adaptation benefits

Economic benefits included income from meat sales, benefits from reduced animal losses, and benefits from reduced additional feed costs for adolescent sheep in winter. **Environmental benefits** include improved grazing capacity and reduced water

consumption due to reduced livestock numbers. Therefore, these returns are included.
The social benefit includes the cost of paying the social insurance of the herdsman when the lambs of the sheep are bought and herded by herdsmen. Because with the creation of additional jobs, social insurance contributions of the labor force will be paid.

In the benefits of adapting to climate change, the amount of greenhouse gases (methane and nitrogen oxides) emitted by sheep will decrease, so it was assumed that the costs of reducing emissions have been avoided. It is climate change adaptation benefits. Let's show the results of the cost-benefit analysis of lamb meat on the example of Bayandelger sum of Sukhbaatar province. In 2024, the number of male adolescent sheep for sale is estimated to be 46,230 in Bayandelger Sum.

Table 2: Plan of Cost-benefit of putting young animals into economic circulation.

	Sell after a year	Lamb feeded only pasture	Lamb feeded Pasture+ rape cake	Lamb feeded Pasture+rape cake+Mimo
Sales revenue (billion.tugrik)	5.85	4.17	4.88	6.53
Prise of pasture grass (billion.tugrik)	7.92	1.73	1.73	1.73
Price of supplementary feed (million.tugrik)	186.58	0	858.25	995.69
Price of water (million.tugrik)	228.56	49.98	49.98	49.98
Cost of reducing greenhouse gases (million.tugrik)	45.53	17.70	17.70	17.70
COST PROFIT (billion.tugrik)	-0.503	2.37	2.22	3.73

- Grass to eat from pastures will decrease from 7.92 billion MNT to 1.73 billion MNT.
- Water consumption will decrease from 228.6 million MNT to 49.9 million MNT.
- 139.9 million MNT additional fodder is needed when the male lamb is kept without selling it. (To get through the winter)
- The cost of reducing greenhouse gas emissions will decrease from 45.53 million MNT to 17.7 million MNT.
- Sales revenue will decrease from 5.85 billion MNT to 4.17 billion MNT.

Summarizing the above results, if the current trend is followed, the sales revenue is already high, but the cost return is -502.6 million MNT. When the lamb is sold, the sales revenue will not reach today's results, but the cost return will be 2.37 billion MNT.

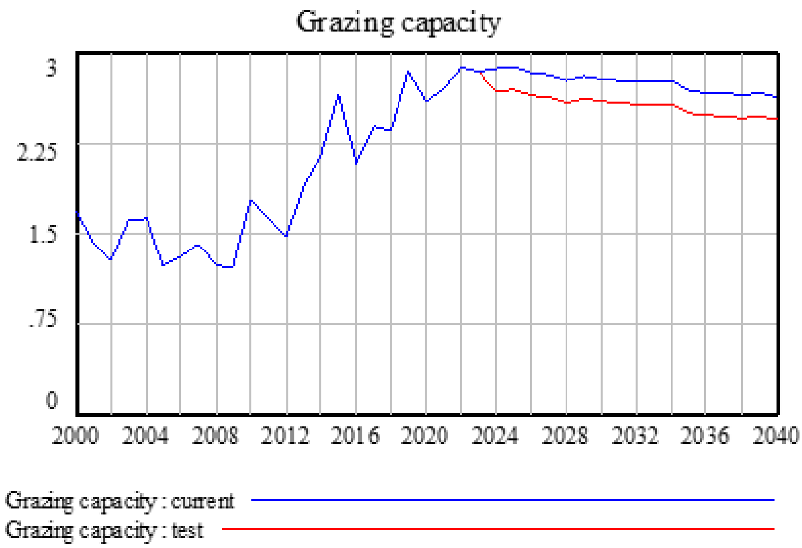


Figure 9: Grazing capacity.

With the production of lamb meat, overgrazing would be 2.7 times in Bayandelger soum instead of estimated 2.9 times in 2024.

5. Conclusions

The overcapacity of pastures and the loss of pastures have become the main reason for desertification, increasing the frequency of droughts in Mongolia, which has fragile and thin soil. As of today, the carrying capacity of Mongolia's pastures is 1.5 times on average, and in some provinces, it has exceeded 2-10 times. Therefore, it has been seen that the establishment of an animal raw material processing plant in Sukhbaatar province, which will reduce the number of grazing animals and increase the income of pastoral families, can reduce the amount of economic damage caused by climate change by 51-55 percent.

If the above animal raw materials processing factories are established and used throughout Mongolia, a total of 28,000 jobs will be added and the gross domestic product will increase by 11.2 percent.

By introducing adolescent animals into the economy, the overcapacity of pastures in Sukhbaatar province will decrease from 1.88 times to 1.4 times. Scenario 7 would reduce economic losses by 14 percent per year. In Scenario 1, economic losses will decrease by 11.7 percent per year.

In Mongolia, if young animals are put into circulation for 1-2 years, the sales revenue is 632.7 billion MNT, but the return on cost is -273.7 billion MNT, but by giving pasture, rapeseed pulp, supplemental feed when selling lambs, the sales revenue will reach the highest 706.3 billion MNT. It has an advantage that the number of wintering animals will decrease by about 5 million.

One of the main reasons why herders do not bring young animals into the economy is the lack of free pasture and water. Also, since the price of animal-derived raw materials is too low and animal-derived raw materials are not processed, the income of herder households is not sufficient. By selling young animals after 1 year, the average income of one herdsman household will increase by MNT 950,000.

References

[1] D. Badarch, B. Ochirbat, B. Enkh-Amgalan , "Fundamentals of System Dynamics Modeling ," Ulaanbaatar, 2003

[2] National Statistics Committee website , www.1212.mn

[3] John D. Sterman, , "Systems Thinking and Modeling for a Complex World ," 2000

[4] D.H.Meadows , "The Limits to Growth ," 1972. New-York

[5] J.W.Forrester, 1958, "Industrial Dynamics-A Major Breakthrough for Decision Makers ," in: Harvard Business Review, Vol. 36, No. 4, pp. 37-66.

[6] A. Bakey, "Scientific basis of sustainable development of agriculture in Mongolia ," Ulaanbaatar, 2020

[7] "Nationally determined contribution targets for the implementation of the goals of the Paris Agreement ," the Government of Mongolia, 2020

[8] G. Ganzorig, "Cost-Benefit Analysis of Disaster Prevention Activities ," Journal of Agricultural Sciences, No. 1, 2008, page 108-113.

[9] www.mimo.mn

[10] G. Sarantuya, "Possibility of research and assessment of the occurrence of Zud in Mongolia ," 1st edition, Ulaanbaatar, 2005, page 46-49, 59-61, https://doi.org/10.1177/00343552050490010901

[11] "Improving the ability to adapt to climate change and risk management of rural people in Mongolia project" 2021.

[12] https://climateknowledgeportal.worldbank.org/country/mongolia/tropical-cyclones-projections

[13] D. Bayanjargal, N. Togtokhbayar "A cost-benefit analysis of smart climate adaptation measures through increasing lamb meat production, reducing the number of livestock overwintering, and mitigating pasture degradation."
Хэрэглээний математик 2021, 2022-1-24, vol. 1, pp. pp.71