# ANALYZING ENVIRONMENTAL AND ECONOMIC VARIABLES OF CLIMATE CHANGE VULNERABILITY IN MONGOLIA

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# Introduction

- In Mongolia, near-surface temperature and its annual mean have increased by 2.24° C between 1940-2015 periods and annual precipitation decreased by 7% (Ministry of Environment and Tourism, Mongolia, 2018).

- Local pastoral socio-economic systems is highly sensitive to climate variability, such as drought, and zud (severe winter conditions causing livestock loss) due to an animal husbandry dominated economy.

- In response to climate change, the Mongolian government has been active in developing policy documents such as Nationally Determined Contribution (NDC) for Paris Agreement, National Adaptation Policy, Law on Climate Change etc.

- However, knowledge and information on current and future impact, risk, and vulnerability to climate change is crucial for an accurate decision making at national and local levels.
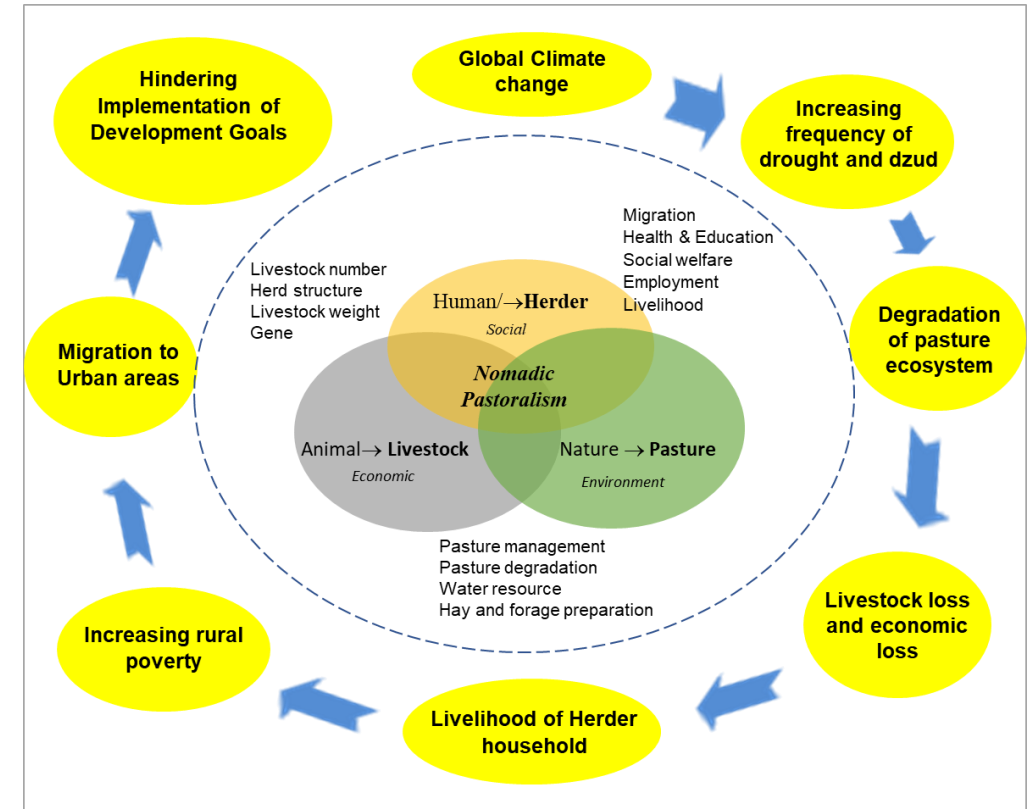
# Background

**Researches abroad (13)**: **climate and disaster 7, environment and agriculture 26, demography 15, economy 14, health 12, education 7, social protection 7, infrastructure and communication 6 variables**

Pandey, R., & Bardsley, D. K. (2015). Social-ecological vulnerability to climate change in the Nepali Himalaya. *Applied Geography*, *64*, 74-86.

Wei, Y., Wang, S., Fang, Y., & Nawaz, Z. (2017). Integrated assessment on the vulnerability of animal husbandry to snow disasters under climate change in the Qinghai-Tibetan Plateau. *Global and Planetary Change*, *157*, 139-152.

Žurovec, O., Čadro, S., & Sitaula, B. K. (2017). Quantitative assessment of vulnerability to climate change in rural municipalities of Bosnia and Herzegovina. *Sustainability*, *9*(7), 1208.

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**Researches in Mongolia:**

Altanbagana et al., (2014): **ecological/agricultural 8, socio-economic 10 variables**

Suvdantsetseg et al., (2020): **ecological 4 variables**

Nandintsetseg et al., (2018): **climate hazard 2, herders' socio-economic vulnerability 7 variables**

Boldbaatar et al., (2022): **climate 6, hazard 5, social 8 variables**

Third National Communication (2018): **climate and environment related 17, agriculture related 6, public health related 2 variables**
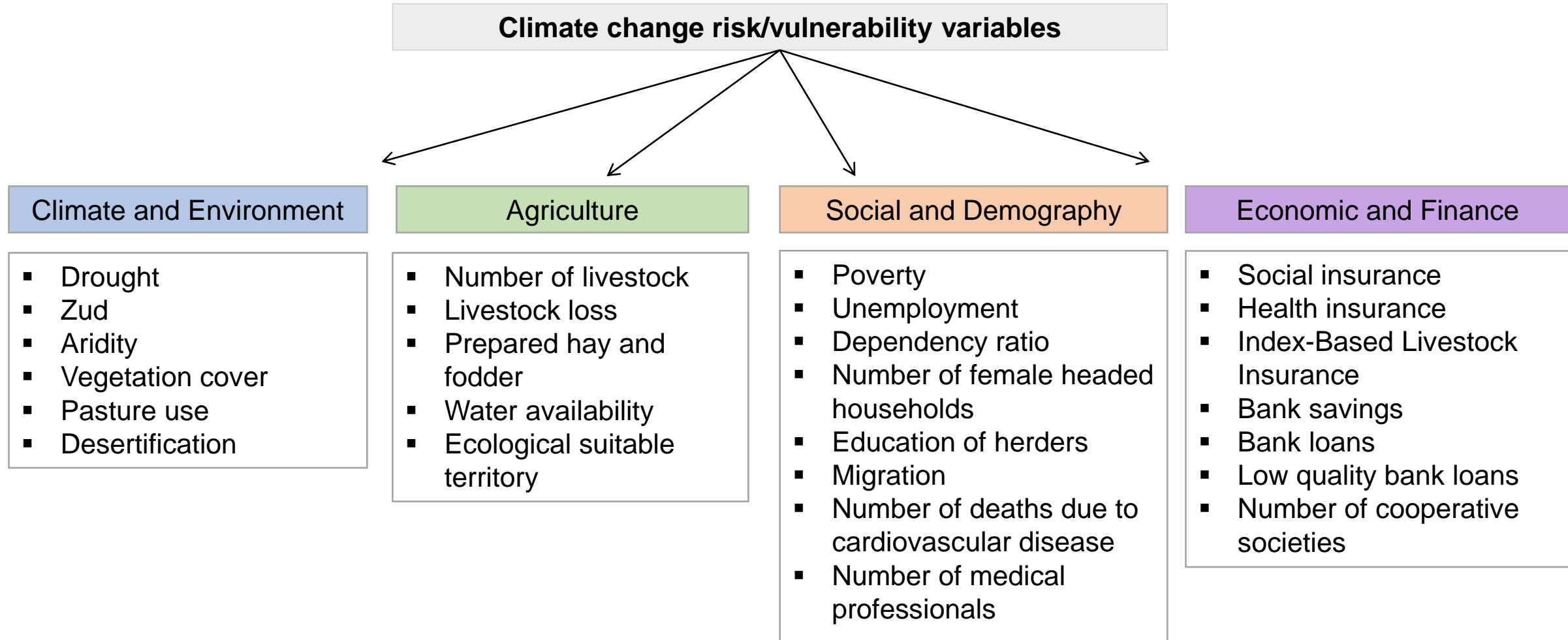
Nationally Determined Contribution Action Plan (2021): **26 adaptation measures, 35 criteria**

➤ However, only few researches have tried to integrate several ecological and socio-economic components into integrated vulnerability assessment and analyzed the relationship between these variables

➤ **The objective** of the research is to calculate and analyze environmental and economic variables of vulnerability to climate change in Khovd province

# Background

➢ Climate change, through **hazards, exposure** and **vulnerability** generates **impacts and risks** that can surpass limits to adaptation and result in losses and damages (IPCC, 2022).

$$V = f(haz, exp, sen, ac, res)$$

| Climate change risk/vulnerability variables | | | |
|---|---|---|---|
| **Climate and Environment** | **Agriculture** | **Social and Demography** | **Economic and Finance** |
| ▪ Drought<br>▪ Zud<br>▪ Aridity<br>▪ Vegetation cover<br>▪ Pasture use<br>▪ Desertification | ▪ Number of livestock<br>▪ Livestock loss<br>▪ Prepared hay and fodder<br>▪ Water availability<br>▪ Ecological suitable territory | ▪ Poverty<br>▪ Unemployment<br>▪ Dependency ratio<br>▪ Number of female headed households<br>▪ Education of herders<br>▪ Migration<br>▪ Number of deaths due to cardiovascular disease<br>▪ Number of medical professionals | ▪ Social insurance<br>▪ Health insurance<br>▪ Index-Based Livestock Insurance<br>▪ Bank savings<br>▪ Bank loans<br>▪ Low quality bank loans<br>▪ Number of cooperative societies |

# Methodology

| ENVIRONMENTAL VARIABLES | | |
|---|---|---|
| **1. Drought-dzud Index** | **2. Aridity** | **3. Vegetation cover** |
| Drought Index $(S_{summer})$   $S_{summer} = \sum_{j=1}^{n}\left(\frac{T_j - \overline{T_j}}{\sigma_T}\right) - \sum_{j=1}^{n}\left(\frac{R_j - \overline{R_j}}{\sigma_R}\right)$<br><br>Dzud Index $(S_{winter})$  $S_{winter} = \sum_{i=1}^{n}\left(\frac{T_i - \overline{T_i}}{\sigma_T}\right) - \sum_{i=1}^{n}\left(\frac{R_i - \overline{R_i}}{\sigma_R}\right)$<br><br>Black Dzud: $S_{winter} = \sum_{i=1}^{n}\left(\frac{T_i - \overline{T_i}}{\sigma_T}\right) + \sum_{i=1}^{n}\left(\frac{R_i - \overline{R_i}}{\sigma_R}\right)$<br><br>$Tj$: monthly mean temperature of the month j<br>$\overline{T_j}$: long period average of monthly mean temperature of month j<br>$R_j$: monthly precipitation on month j<br>$\overline{R_j}$: long period average of monthly precipitation on month j<br>$\sigma_T$: standard deviation of the monthly mean temperature of the year<br>$j$: month (forest and grassland month 5, 6, 7, desert month 5, 6, 7, 8)<br>$$\Delta S = S_{summer} - S_{winter}$$<br>$S_{summer} \gg 0$ drought intensity is high<br>White dzud:  $R_j \gg 0\ T_j \ll 0\ S_{winter} \ll 0$  байна<br>Normal: $\bar{R} * 0.2 < R_j < \bar{R}$<br>Black dzud: $R_j < \bar{R} * 0.2$ бөгөөд $T_j \ll 0$ үед<br><br>Drought-Dzud index:<br>$$\Delta S = S_{summer} - S_{winter}$$<br>$\Delta S$: drought-dzud index<br>$\Delta S \gg 0$ high intensity of drought and dzud | Mezentsev index had highest correlation with yearly ecosystem productivity in Mongolia (Mandakh, 2014). In Mongolia, it varies between 0.02-0.6 and in high mountain region it reaches 1.<br><br>$$MI = \frac{P}{[0.2 \sum T_{>10°C} + 306]}$$<br>P: Total precipitation of the year<br>$T_{>10°C}$: monthly mean temperature above 10 degrees | Modified Soil Adjusted Vegetation Index (MSAVI)<br>One of the important indicators of grassland ecosystem services is plant biomass. NDVI is a measure of green vegetation density and biomass based on satellite data. MSAVI is improved on NDVI to account for soil and air effects, making it suitable for measuring bare land.<br><br>$$MSAVI = \frac{\left(2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - R)}\right)}{2}$$ |
| • ERA5 reanalysis data of monthly average temperature at 2m above the surface of land (1981-2022)<br>• The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) of monthly total precipitation (1981-2022) | | • Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared (TIRS) Collection 2 Level-2 Science Products 30-meter multispectral data<br>• Period: 1st of July -20th of August, 2013-2022 |

# Methodology

| ECONOMIC AND FINANCIAL VARIABLES | | | |
|---|---|---|---|
| **1. Social insurance** | **2. Health insurance** | **3. Index-Based Livestock Insurance** | **4. Number of cooperative societies** |
| $$SIR = \frac{N_{SI}}{N_{herder}}$$ SI: Social insurance coverage rate $N_{SI}$: Number of herders covered by social insurance $N_{herder}$: Number of herders in the soum | $$HIR = \frac{N_{HI}}{N_{herder}}$$ HI: Health insurance coverage rate $N_{HI}$: Number of herders covered by health insurance $N_{herder}$: Number of herders in the soum | $$LIR = \frac{N_{LI}}{N_{HH}}$$ HI: Index-based livestock insurance coverage rate by livestock $N_{LI}$: Number of livestock covered by index-based livestock insurance $N_{herder}$: Number of livestock in the soum | $$CSR = \frac{N_{CS}}{N_{population>15}} * 100$$ CSR: Percentage of people in cooperative societies $N_{CS}$: Number of people in cooperative societies $N_{population>15}$: Population of the soum above the age of 15 |
| **5. Bank savings** | **6. Bank loans** | **7. Low quality bank loans** | |
| $$BS = \frac{BS_{total}}{N_{population}}$$ BS: Bank savings per person $BS_{total}$: Total bank saving of the soum $N_{population}$: Population of the soum | $$BL = \frac{BL_{total}}{N_{population}}$$ BS: Bank loan per person $BS_{total}$: Total bank loan of the soum $N_{population}$: Population of the soum | $$BL = \frac{BL_{total}}{N_{population}}$$ BS: Low quality bank loan per person $BS_{total}$: Total low quality bank loan of the soum $N_{population}$: Population of the soum | |

# Research Area

## KHOVD  province of Mongolia

- Khovd province has 17 soums, 91 bags, with population of 90.3 thousand, 23.3 thousand households, annual gross domestic product is 710.2 billion MNT, which is an average of 7.7 million MNT per person.
- The agricultural sector, which is the main sector of the province's economy, accounts for 46.3% of the total domestic product production, or 328.8 billion MNT. 8541 herder families are engaged in animal husbandry production and 12498 herders are working in the agriculture sector.
- Khovd province is located in the high mountain region of Altai Mountains. Around 20 percent of the province is desert steppe.
- Khovd province was one of the 6 provinces to be classified as very risky to climate change (Ministry of Environment and Tourism, Mongolia, 2018), and is one the most vulnerable prefectures in Mongolia to climate change according to a pastoral, socio-economical vulnerability assessment (Togtokh et al., 2017).
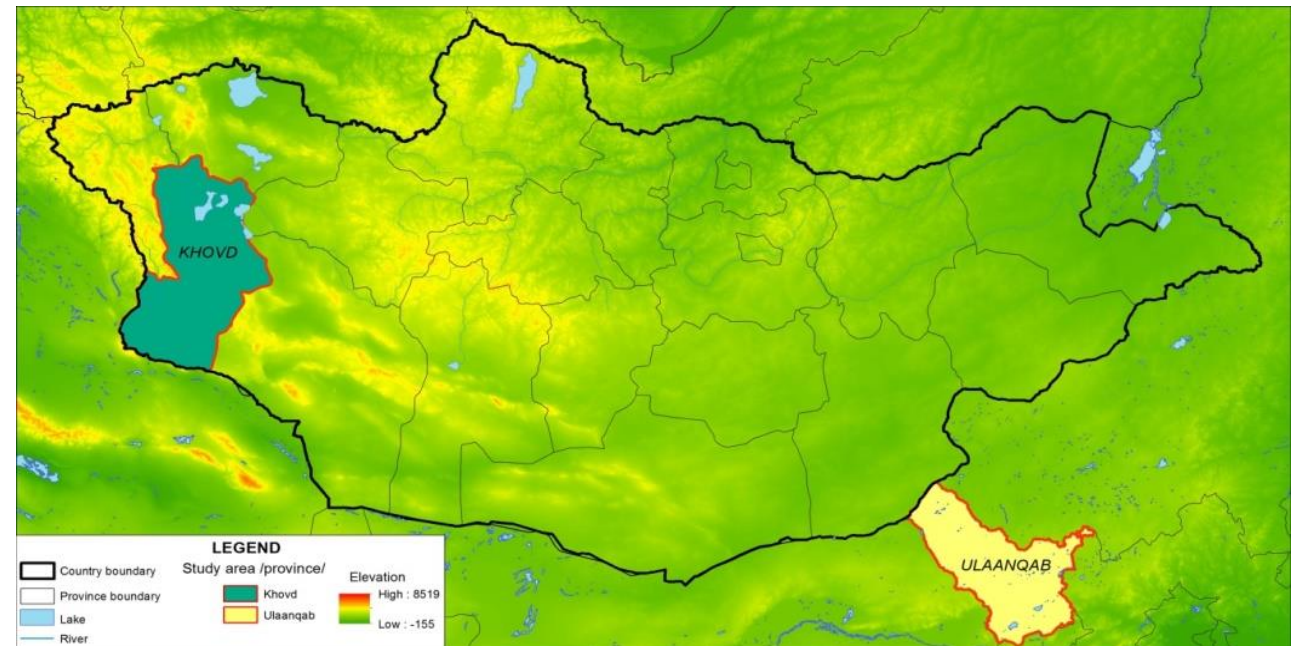
# Methodology

1. **Calculation of each variables**

2. **Analyze trend of the variables**

   a. Linear regression (Ordinary Least Square): The OLS minimizes the sum of the squared residuals

   b. Mann-Kendall test: Non-parametric statistical test that measures consistency of a trend. The test is a cumulative value of the instances of increases or decreases from a pairwise comparison, with values of +1 indicating a continually increasing and −1 a continually decreasing trend.

   c. Sen's Slope: non-parametric method requiring the test data independent and insensitive to missing and abnormal data. Slope >0 means the upward trend and the slope <0 means the downward trend.

   $$Slope = Median \left[ \frac{X_j - X_i}{j - i} \right]$$

**3. Normalize each variables**

   - If the variable has positive relationship to vulnerability:

   $$N_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \qquad (1)$$

   - If the variable has negative relationship to vulnerability:

   $$N_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} \qquad (2)$$

# Results

1. **Drought-dzud Index** in 17 soums of Khovd province
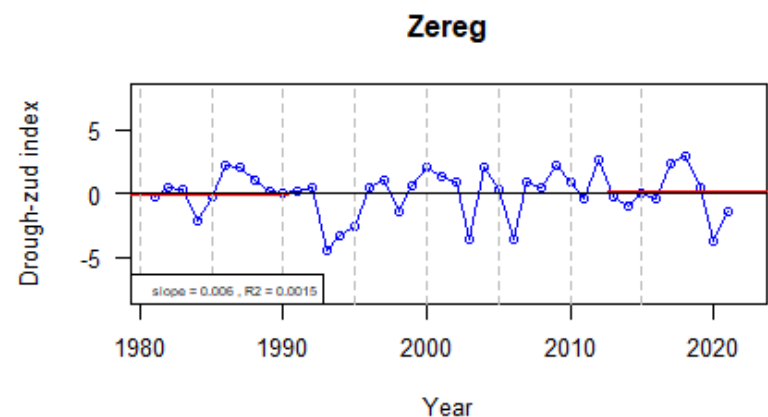


> ➤ In northern region including Khovd, Buyant, Erdeneburen, Duut, Munhhairhan soums, drought-dzud index increasing trend in drought-dzud occurence
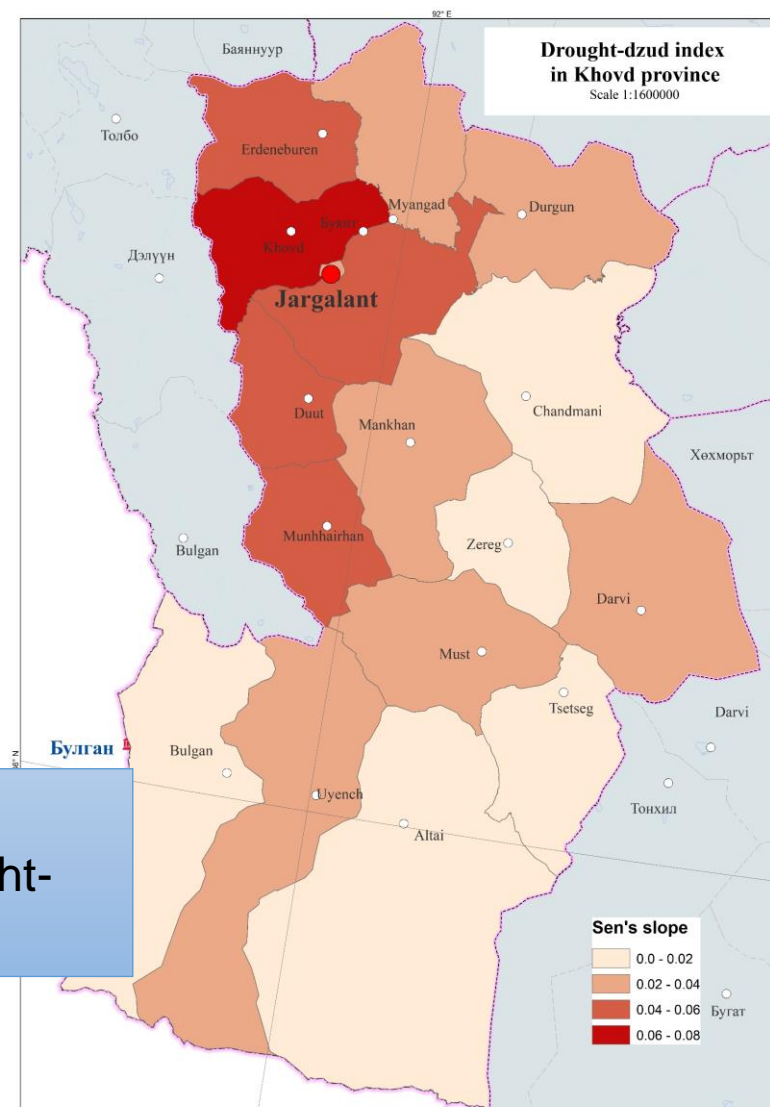
Figure 1. Drought-dzud index (1981-2021), Sen's slope of drought dzud index

2. **Aridity Index** in 17 soums of Khovd province
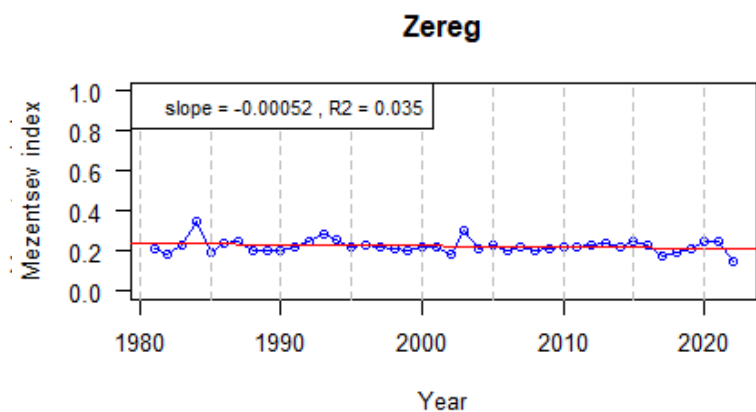


> In northern soums including Buyant, Erdeneburen, Myangad, Durgun soum has increasing trend in aridity, while Chandmani and Zereg soum has slight decreasing trend in aridity
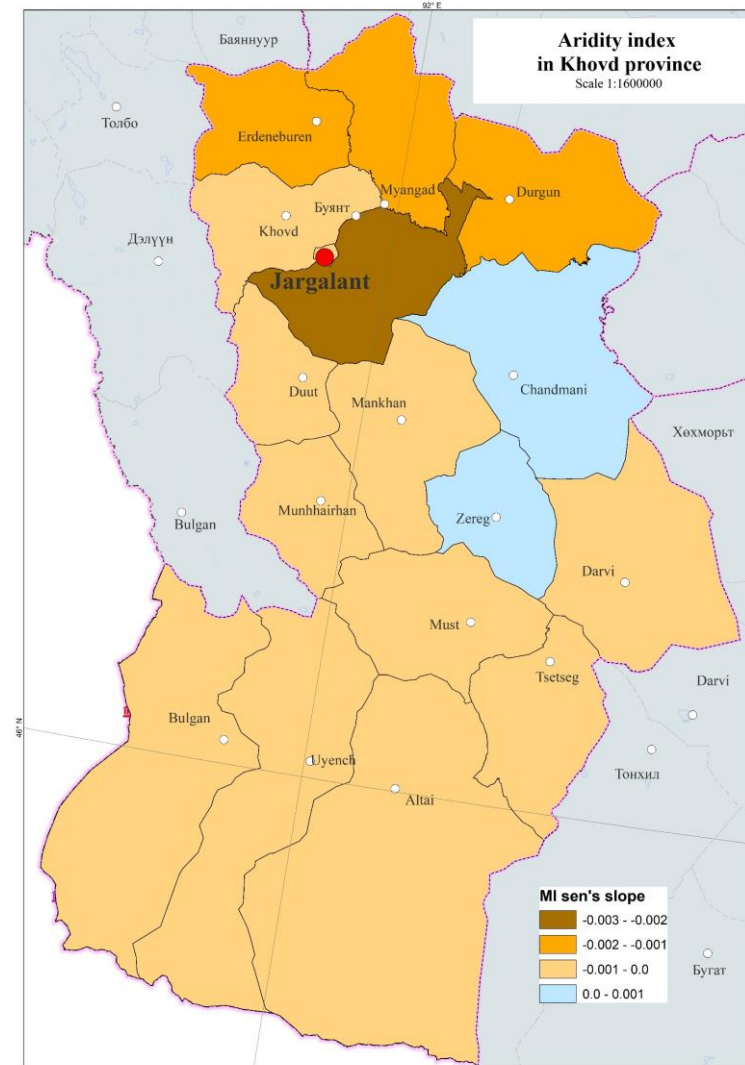
Figure 2. Aridity index (1981-2021), Sen's slope of aridity index

3. **Vegetation cover** in 17 soums of Khovd province
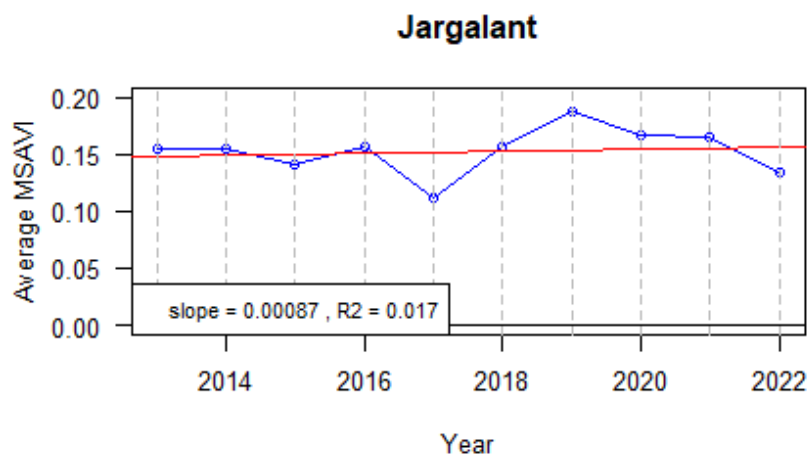


> In Erdeneburen, Duut, Myangad, Durgun has trend of vegetation increase, while central and southern region of Khovd province has decreasing trend of vegetation in the last 10 years
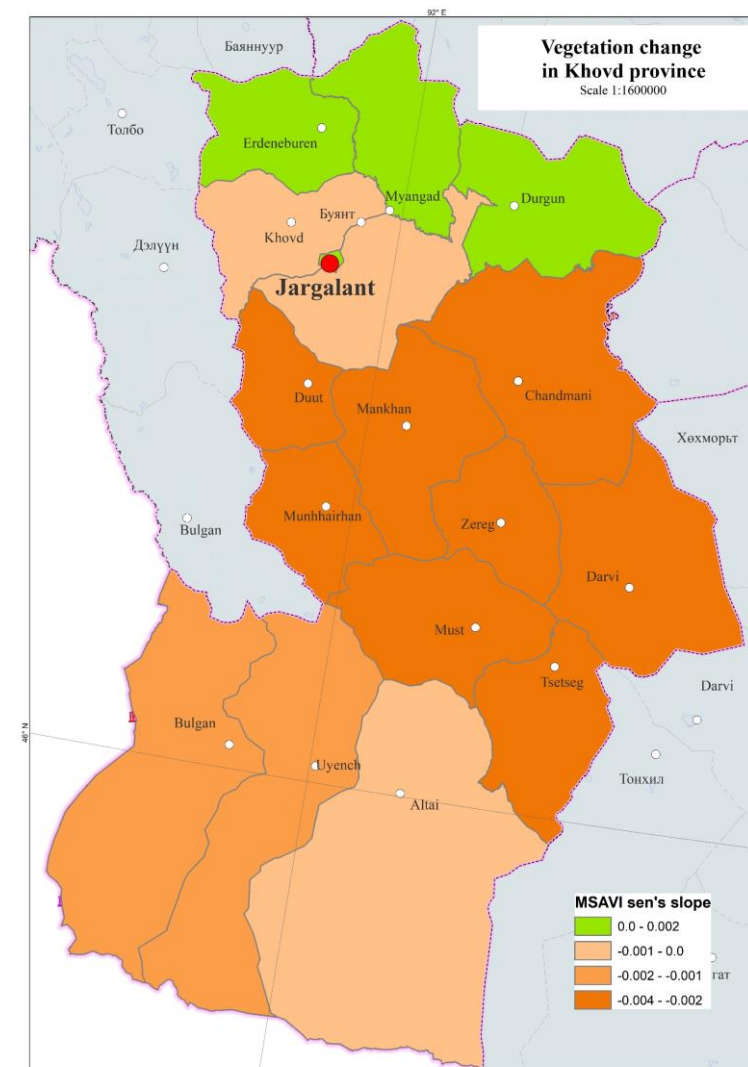
Figure 3. Vegetation index (2013-2022) and Sen's slope of vegetation index

## 4. **Bank savings** in 17 soums of Khovd province

- ➤ Bank savings in Khovd is increased 6 times since 2010, still is less than national average.
- ➤ Durgun, Myangad, Erdeneburen soums have least bank savings per person in Khovd province, thus making it more vulnerable
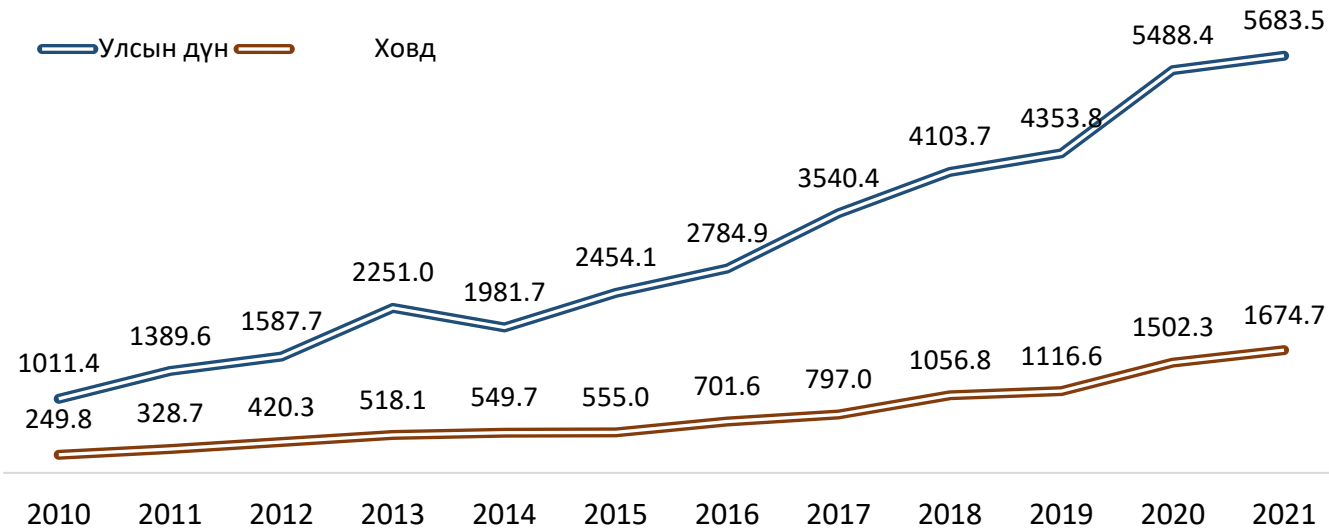


Figure 4. Change of bank saving per person in Mongolia and Khovd province, thousand tugrug

(Улсын дүн, Ховд)

National figures: 1011.4, 1389.6, 1587.7, 2251.0, 1981.7, 2454.1, 2784.9, 3540.4, 4103.7, 4353.8, 5488.4, 5683.5

Khovd figures: 249.8, 328.7, 420.3, 518.1, 549.7, 555.0, 701.6, 797.0, 1056.8, 1116.6, 1502.3, 1674.7

Years: 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021
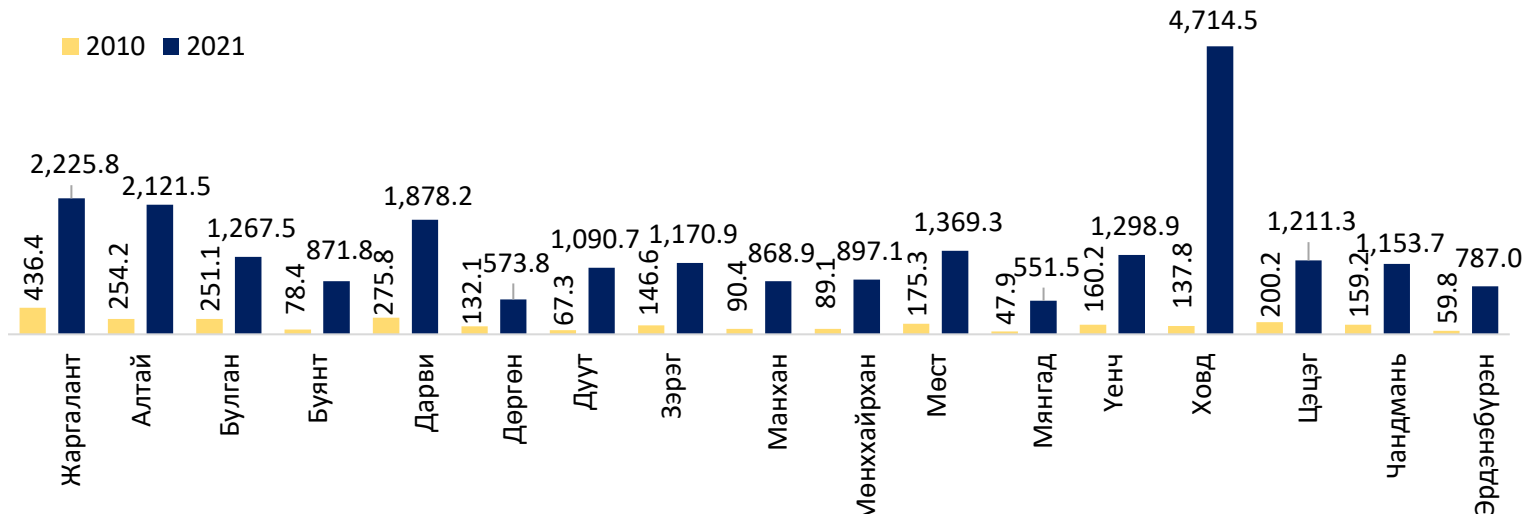


Figure 5. Bank saving per person in Khovd province, thousand tugrug

(2010, 2021)

| Soum | 2010 | 2021 |
|------|------|------|
| Жаргалант | 436.4 | 2,225.8 |
| Алтай | 254.2 | 2,121.5 |
| Булган | 251.1 | 1,267.5 |
| Буянт | 78.4 | 871.8 |
| Дарви | 275.8 | 1,878.2 |
| Дөргөн | 132.1 | 573.8 |
| Дуут | 67.3 | 1,090.7 |
| Зэрэг | 146.6 | 1,170.9 |
| Манхан | 90.4 | 868.9 |
| Мөнххайрхан | 89.1 | 897.1 |
| Мөст | 175.3 | 1,369.3 |
| Мянгад | 47.9 | 551.5 |
| Үенч | 160.2 | 1,298.9 |
| Ховд | 137.8 | 4,714.5 |
| Цэцэг | 200.2 | 1,211.3 |
| Чандмань | 159.2 | 1,153.7 |
| Эрдэнэбүрэн | 59.8 | 787.0 |



Figure 6. Average Bank savings per person of the last 10 years in Khovd province

## 5. **Bank loan** in 17 soums of Khovd province
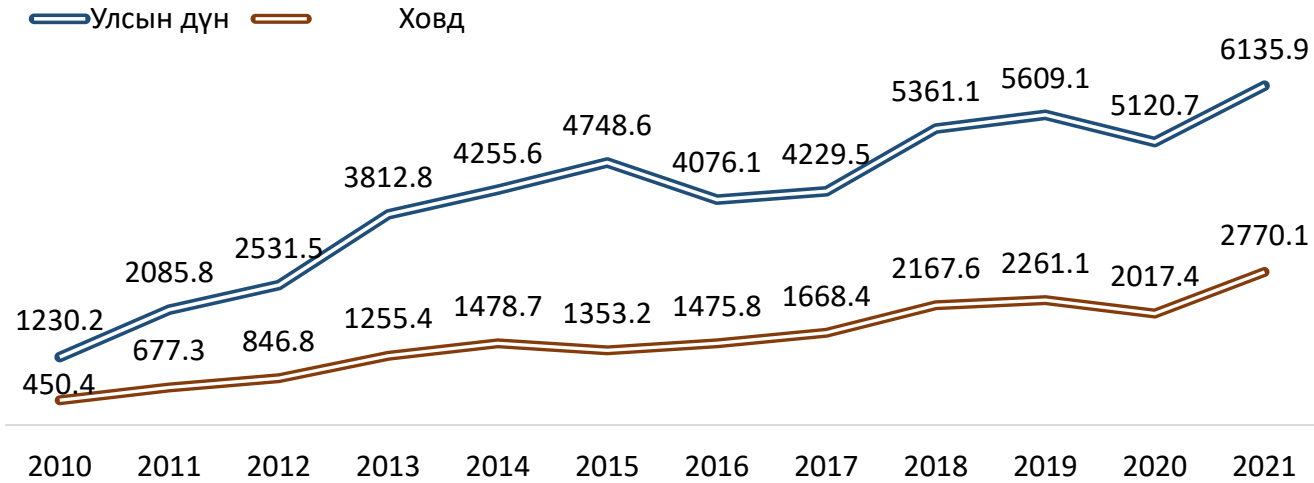
- Bank loans in Khovd is increased 6 times since 2010
- Among Khovd province, Uench, Duut, Manhan, Bulgan soums has the most bank loans making it more vulnerable



Figure 7. Change of bank loan per person in Mongolia and Khovd province, thousand tugrug
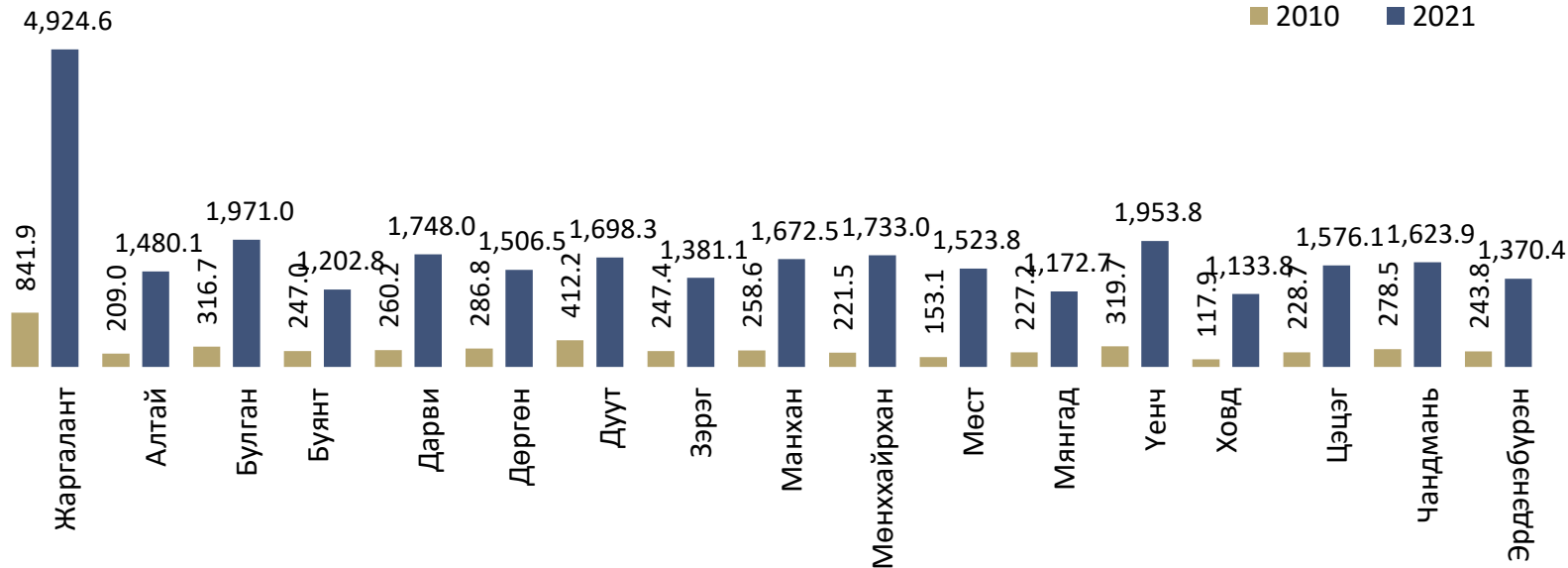


Figure 8. Bank loan per person in Khovd province, thousand tugrug



Figure 9. Average Bank loans per person since 2010 in Khovd province

6. **Low quality bank savings** in 17 soums of Khovd province



Figure 10. Change of bank loan per person in Mongolia and Khovd province, thousand tugrug
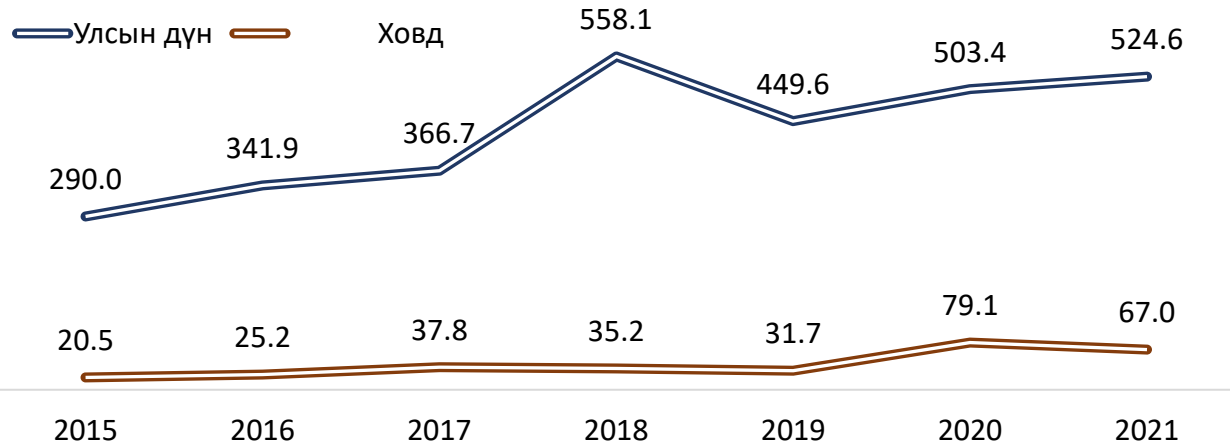
➤ Low quality bank loans Mongolia has increased about twice, and in Khovd increased 3 times in the last 6 years
➤ Among Khovd province, Uench, Tsetseg, Buyant, Bulgan soums and Khovd city has the most low quality bank loans, making it more vulnerable
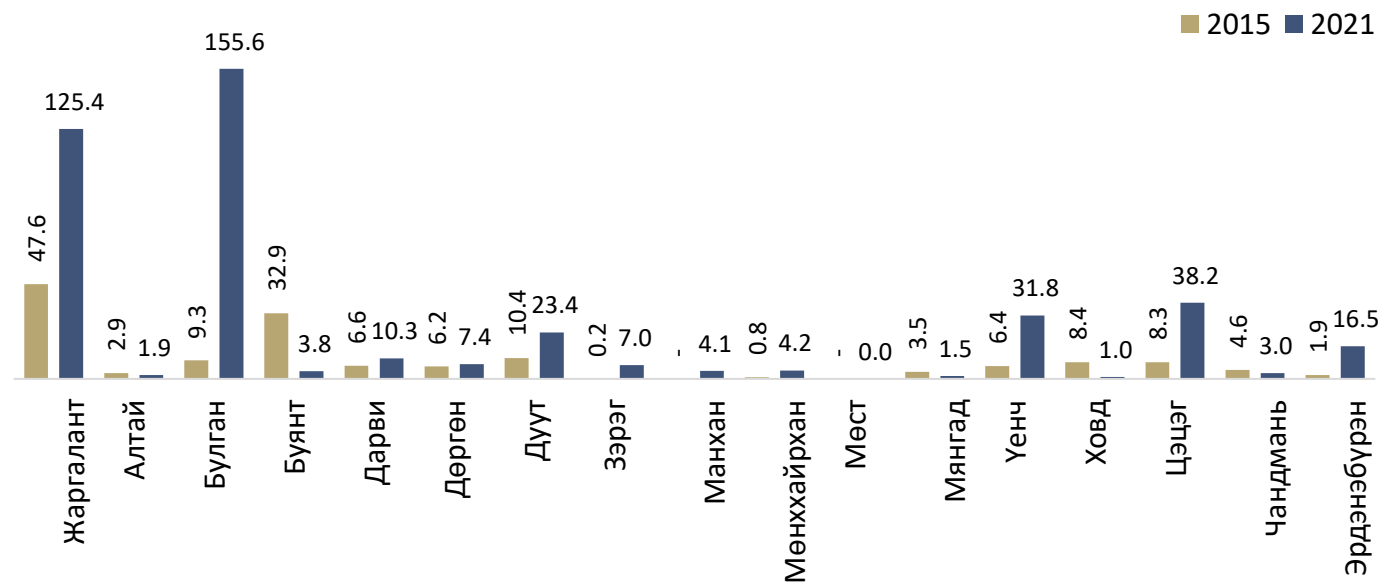


Figure 11. Low quality bank loan per person in Khovd province, thousand tugrug
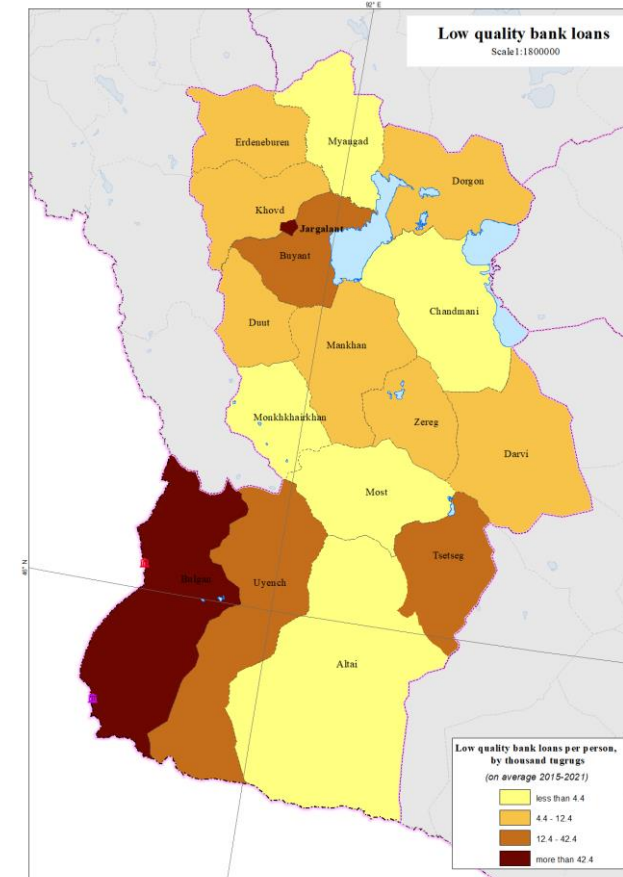


Figure 12. Average Low quality bank loans per person of the last 10 years in Khovd province

# Results

## 7. **Index based livestock insurance** in 17 soums of Khovd province
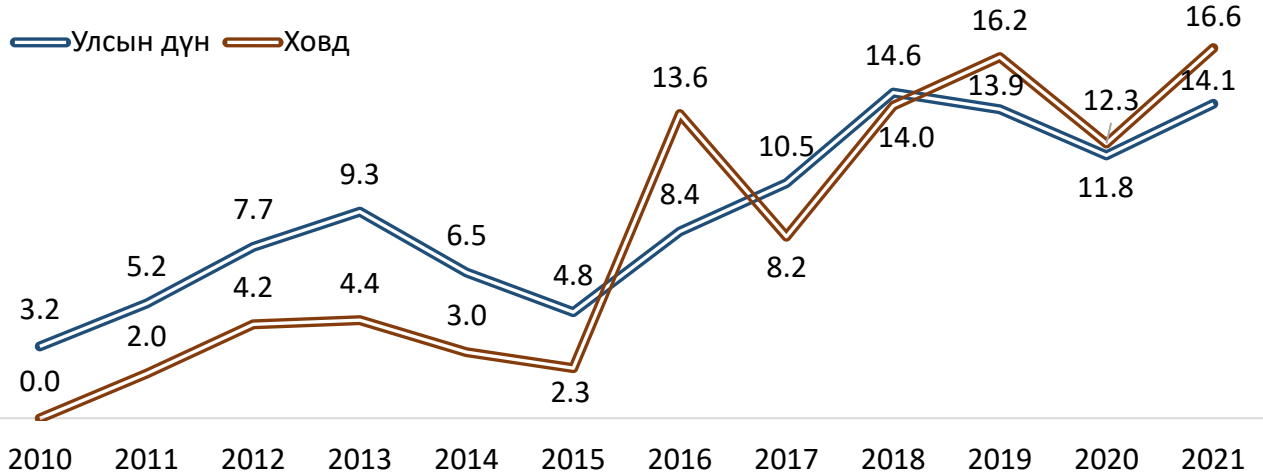
- Index-based livestock insurance in Khovd has fluctuated greatly, but increased over the years.
- Among Khovd province, Uench, Altai, Bulgan soums has the lowest Index-based livestock insurance coverage rate, making it more vulnerable



Figure 13. Index based livestock insurance coverage rate in Mongolia and Khovd province, %
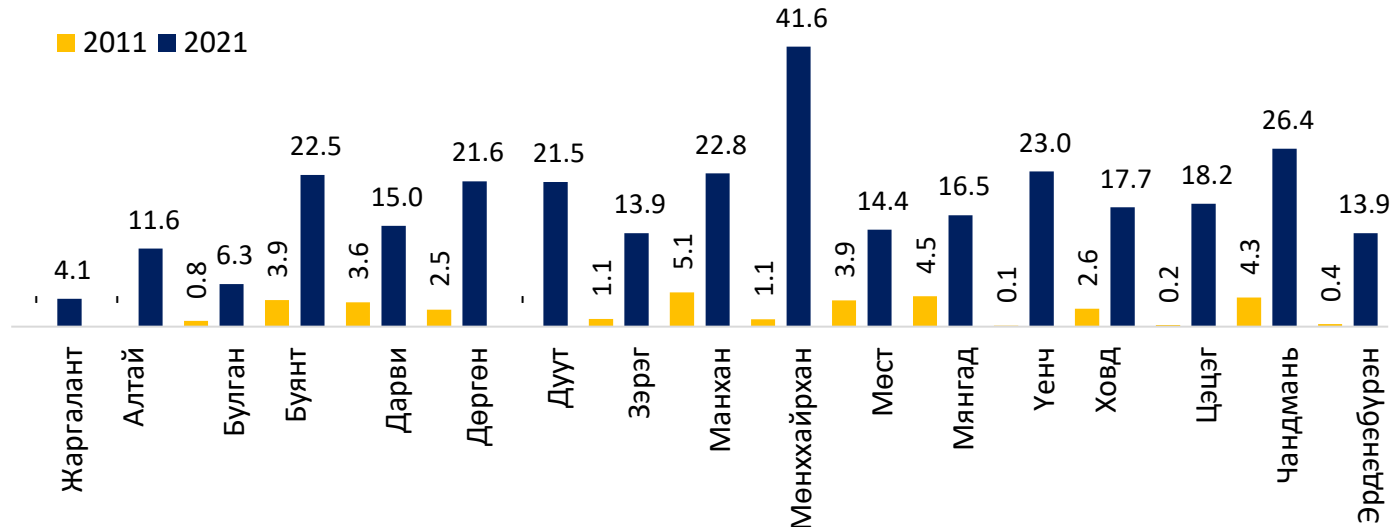


Figure 14. Index based livestock insurance coverage rate in Khovd province, %
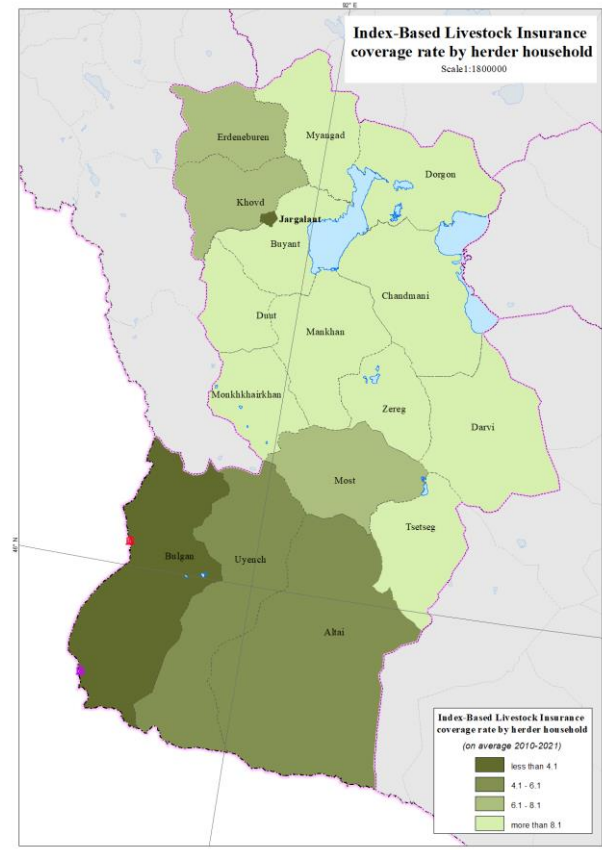


Figure 15. Index-based livestock insurance coverage rate in Mongolia and Khovd province of the last 10 years in Khovd province

## 8. Number of cooperative societies in 17 soums of Khovd province

— Улсын дүн  — Ховд

Figure 16. Percentage of people in cooperative societies in Mongolia and Khovd province, %
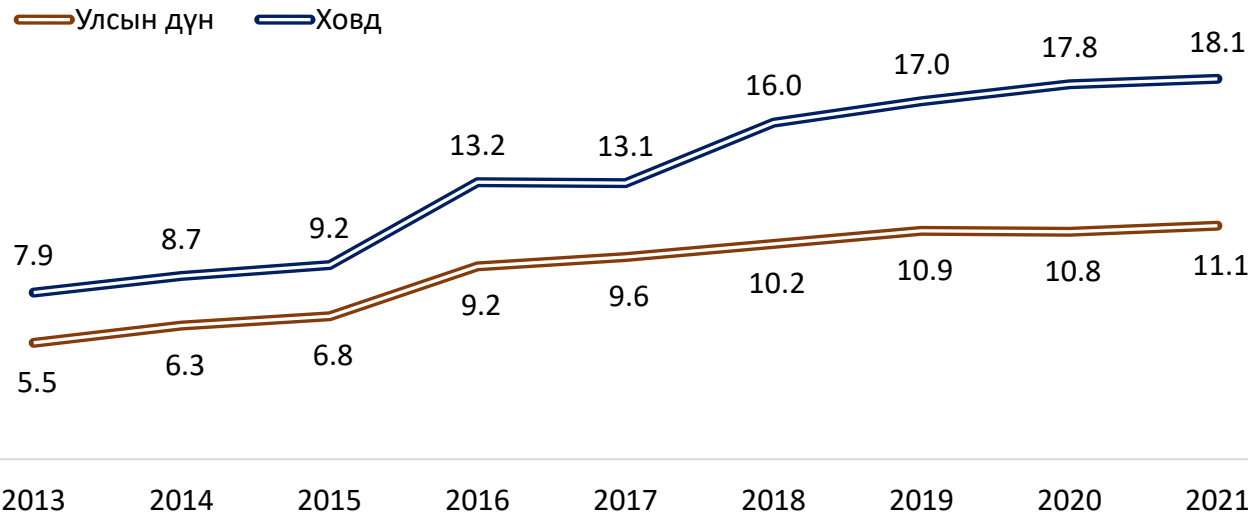
> Number of people in cooperative societies in Khovd and in Mongolia has increased over the years. Khovd province has higher rate of people in cooperative societies.

> Among Khovd province, Khovd, Buyant, Bulgan soums have least number of people in cooperative societies, making it more vulnerable
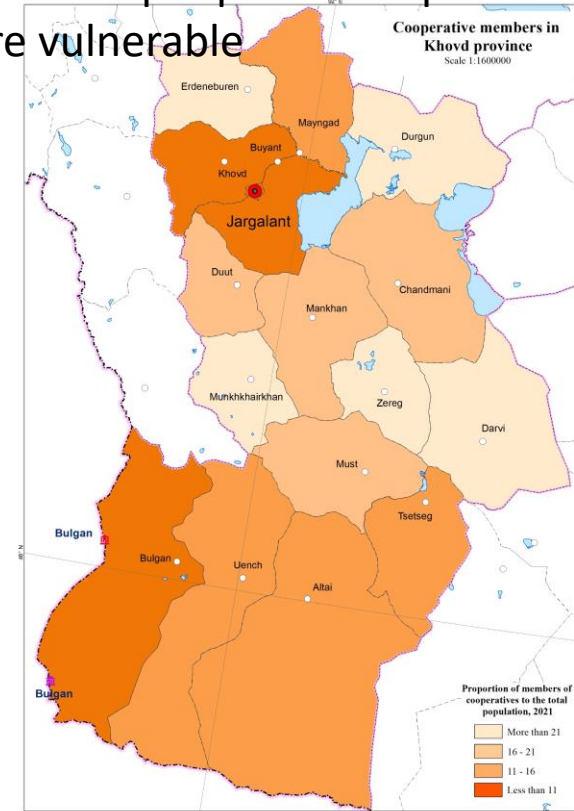


Figure 18. Percentage of people in cooperative societiesin Khovd province 2021

■ 2013  ■ 2021

Figure 17. Percentage of people in cooperative societies in Khovd province, %

8. **Health and Social insurance** coverage rate of herders in 17 soums of Khovd province



Figure 20. Percentage of people with social and health insurance in Khovd province (2021), %
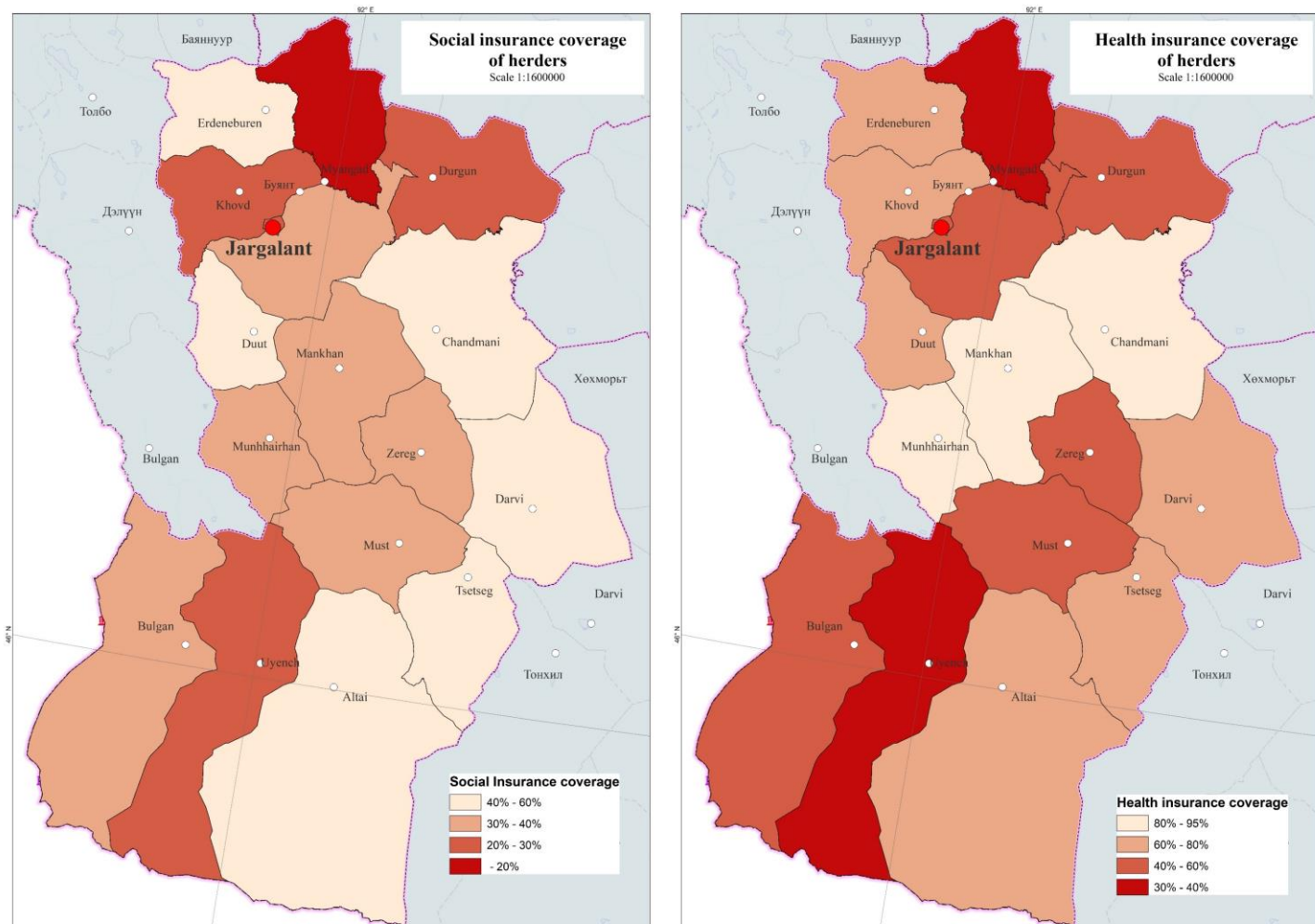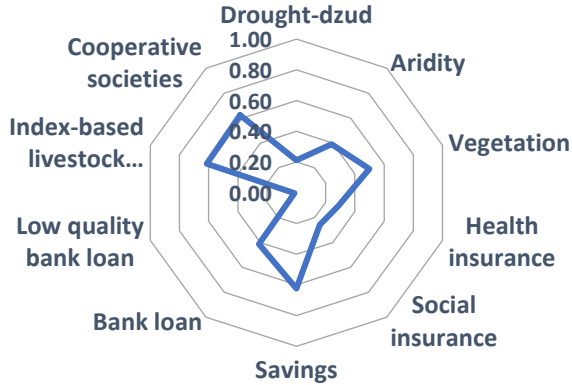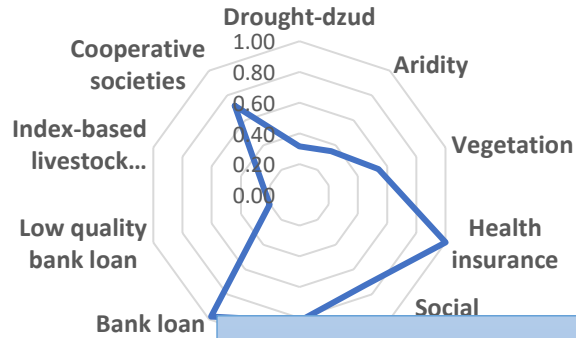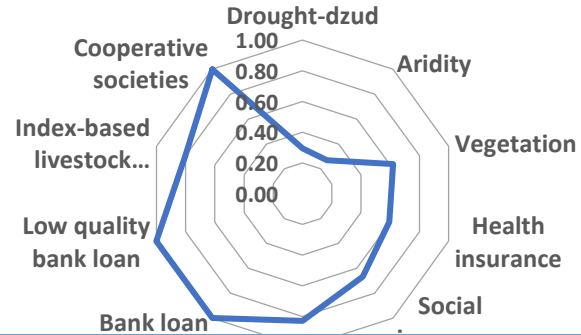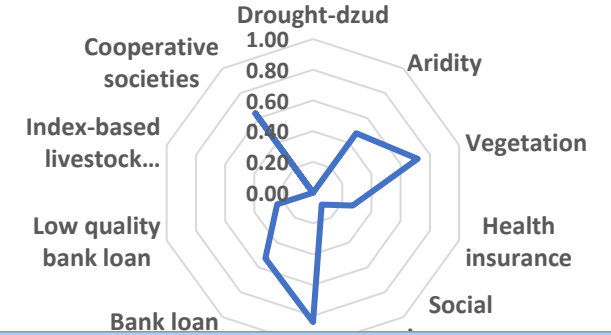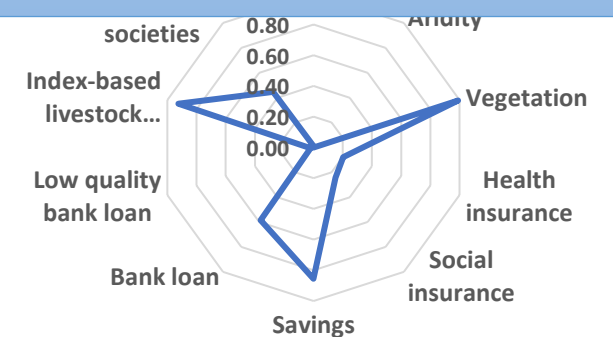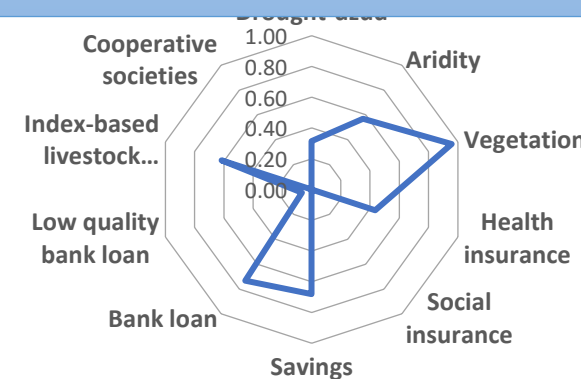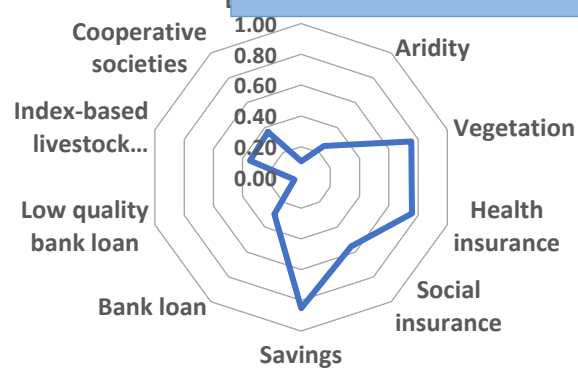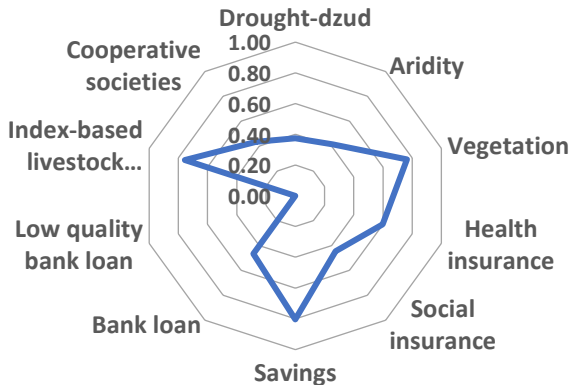
➢ Average health insurance coverage rate is higher than the average social insurance coverage rate.

➢ Herders in the Southern and Northern region has been covered by social and health insurance

# Results



Figure 21. Normalized value of vulnerabilty variables in each soums
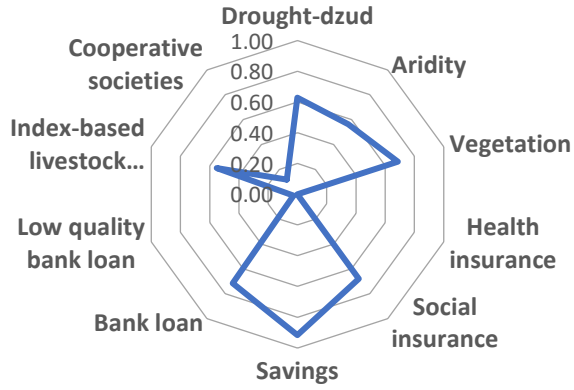
> ➢ High vulnerability in environment variables, especially in the northern and central region, more frequent in Khovd, Buyant, Erdeneburen soums
> ➢ High vulnerability in social variables are observed in different soums depending on the social variable, more frequent in southern region including Bulgan, Uyench, Altai soums
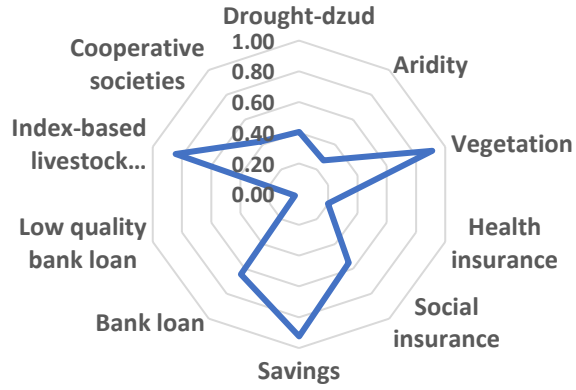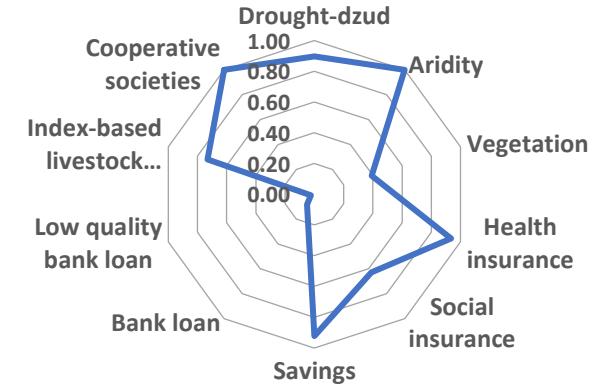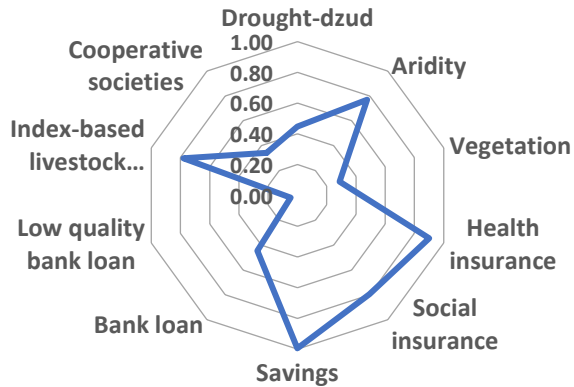
# Results
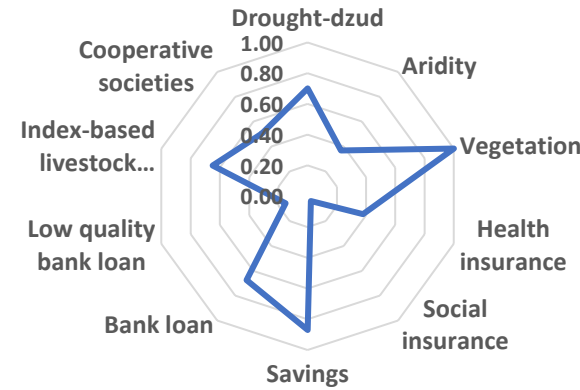


Figure 22. Normalized value of vulnerabilty variables in each soums
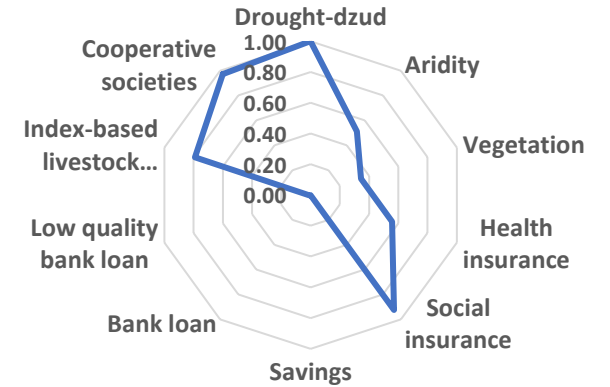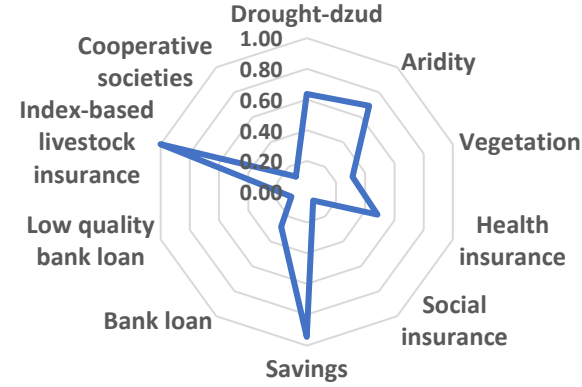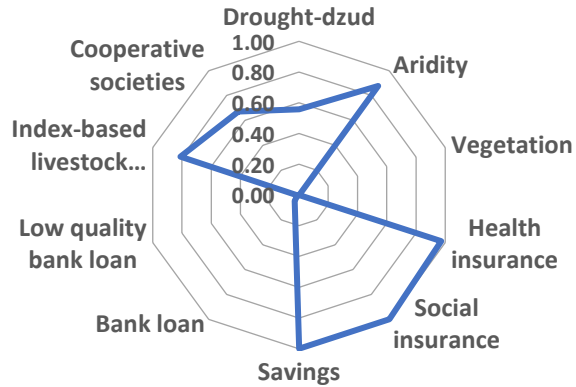
> ➤ Every soum has different set of vulnerabilities depending on their environmental and social characteristics

# Conclusion

**Analysis of variables by each soum:**
- ➢ High vulnerability in environment variables, especially in the northern and central region, more frequent in Khovd, Buyant, Erdeneburen soums
- ➢ High vulnerability in social variables are observed in different soums depending on the social variable, more frequent in southern region including Bulgan, Uyench, Altai soums
- ➢ Every soum has different set of vulnerabilities depending on their environmental and social characteristics

**Discussion:**
- ➢ It is necessary to understand the reason behind the numbers and relationship between vulnerability variables
- ➢ In dept statistical analysis of vulnerability variables are needed

# Thank you for you attention