An investigation into the effects of intensive grazing on soil productivity in Terelj National Park, Mongolia

Word count: 1890

1.Identifying the Context

Research question

Does intensive grazing by large numbers of cows in the Mongolian steppes reduce soil productivity?

Environmental issue

Decreasing plant diversity and vegetation cover due to increasing intensive grazing:

Pastoral farming is the main agricultural activity in Mongolia. Mongolia owns an estimated number of 70 million cattle and about one-third of Mongolians are nomadic livestock herders. Pastureland for grazing occupies 74.25% of total land.
I spent the summer with my herder relatives in the countryside. I noticed that areas where their cows usually graze have relatively sparse and short vegetation. Bordering this pastureland was a tourist camp that enclosed its land with fences. This area was fenced to keep cattle from entering and grazing there. Consequently, this area had tall and dense vegetation. Plant diversity also differed in these areas-the pastureland had mainly grasses only while the fenced area contained many colourful flowers on top of grass.
Intensive grazing directly impacts soil quality and texture by removing vegetation cover, further leading to soil degradation, erosion and loss of fertile soil. In serious cases, the damage can worsen as desertification takes place. Soil degradation is only increasing each year, making it a big environmental problem to Mongolia. 64.7% of Mongolia's total land has been affected by desertification to a certain degree and 12.52% of the land has been degraded. This is also a global issue as "it is estimated that, worldwide, 5-7 million hectares of land valuable to agriculture are lost every year through erosion and degradation."[1]

Connecting the environmental issue to the research question

My research question seeks to investigate the impact of intensive grazing on soil productivity. Soil productivity is the capacity of soil to support plant growth. This relates to the environmental issue because soil productivity is reflected through the volume of growing vegetation. Plant species diversity and vegetation cover, therefore, can signify the level of soil productivity. Species diversity is considered as a function of two components: the number of different species and the relative numbers of individuals of each species.[2] Consequently, I observed the species diversity as well as the individual abundance of plant species in two different areas-a grazing plain and a fenced area in Terelj National Park, Mongolia.

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[1] Loftas, Tony. *"Restoring the Land"*. *Dimensions of Need: an Atlas of Food and Agriculture*. Rome: Food and Agriculture Organization of the United Nations., 1995. Retrieved from: http://www.fao.org/3/u8480e/U8480E0D.htm

[2] Davis, Andrew, and Garret Nagle. *Environmental Systems and Societies*. London: Pearson Education Limited, 2015. p.138

2.Planning

Hypothesis with justification

I predicted a higher plant diversity and denser vegetation cover in the fenced area. This is because the fence restricts entrance and keeps cattle from grazing in that area. As a consequence, the vegetation in the fenced area remains untouched. Meanwhile, in the pasture, a large number of local cattle graze freely, removing much of the vegetation.

Justifying sampling strategy

Plant diversity was measured using quadrats because plants are non-motile organisms. I used random sampling to prevent possible personal bias because I might show preference to areas with higher or lower vegetation cover when choosing my sampling area. Random sampling also gives each plant an equal chance of being picked. I used a 1m x 1m quadrat with a total of 100 smaller squares. Each small square is measured 10cm x 10cm. I chose a 1m quadrat because both of my sampling areas are vast and big. It was then divided into smaller quadrats because I will be working with smaller species such as grass. I pre-determined the areas of my investigation by using a random number generator website to ensure true randomness and also to collect data efficiently.

Identifying the variables

Independent: Type of land investigated (grazing pasture land or fenced area with no livestock)

Dependent: Plant species diversity and vegetation cover

Controlled: I observed each area on the same day so that there would be no impact from weather change. I also made sure I investigated the same total area of each land type, if not identical.

Methodology

A.Choosing sampling areas

The two sampling areas I chose are both located in the Gorkhi-Terelj National Park, approximately 50m away from each other. Area **A** is a pasture where the local cattle(majority consisting of cows) graze and area **B** is a piece of land, owned by a tourist camp and is fenced to protect the vegetation from cattle and keep the aesthetic value for tourists to enjoy. Choosing these two distinct areas allowed me to make an effective comparison and assess the impact of grazing.

1. Lay two 20m measuring tapes perpendicular to each other in both study areas. Ensure they are secured to the ground as this can alter results.

2. Divide each study area into 1m intervals which is the length of one quadrat to be used.

3. Using the random number generating website https://www.random.org/, select two coordinates per one sampling attempt- one for the X-axis and one for the Y-axis. Use the same website every time to ensure full reliability and fairness.

4. Draw an XY graph representing the taped areas and plot the coordinates.

5. Repeat step four 5 times for each sampling area.

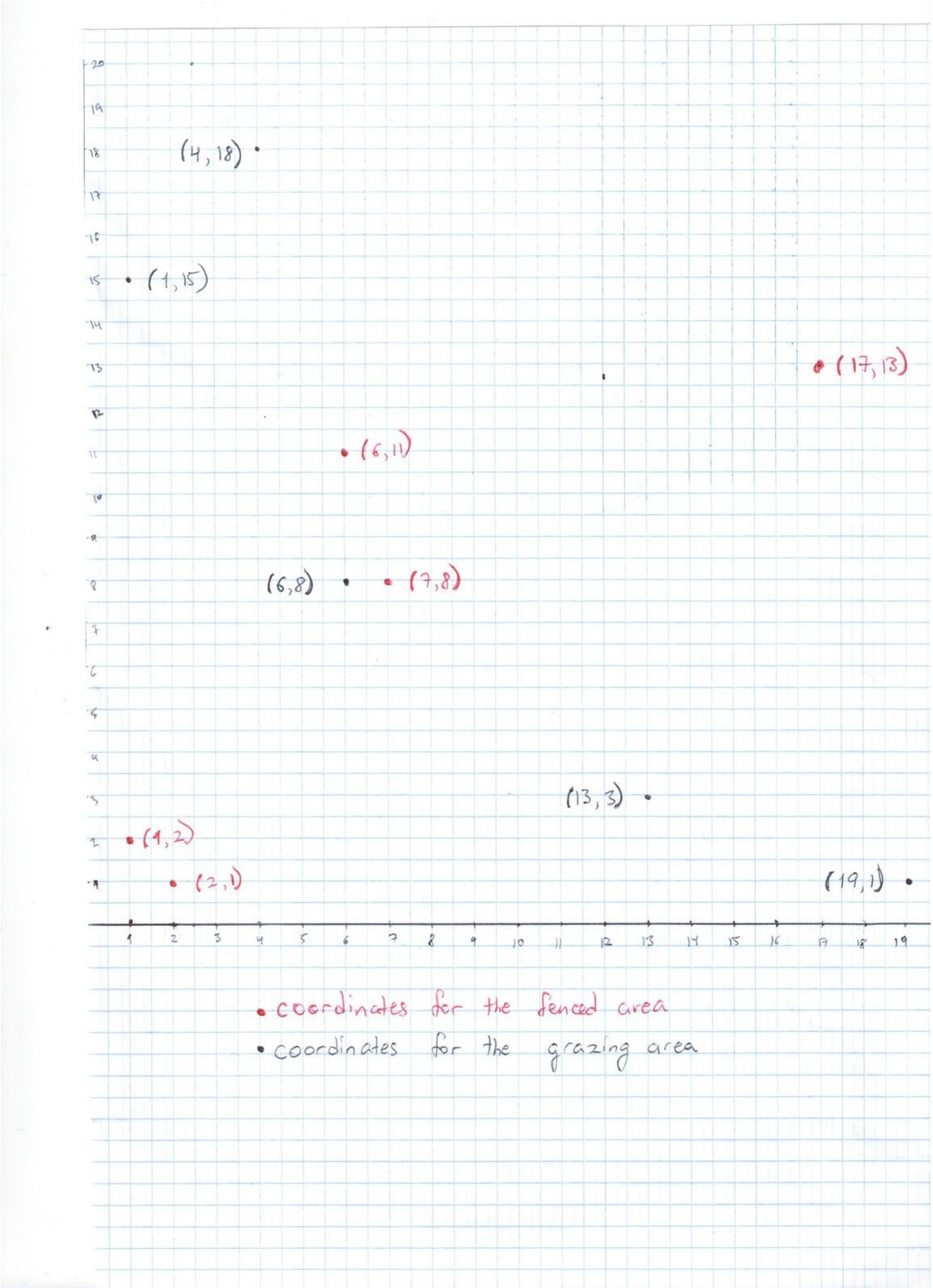

Figure 1 *An XY graph representing the sampling coordinates for both areas to use for further reference during investigation*

	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
X axis	19	4	13	6	1
Y axis	1	18	3	8	15

Table 1.1 *Coordinates generated for grazing area*

	Quadrat 1	Qudrat 2	Quadrat 3	Quadrat 4	Quadrat 5
X axis	1	7	2	17	6
Y axis	2	8	1	13	11

Table 1.2 *Coordinates generated for fenced area*

Figure 2*: On the right:fenced area, on the left: grazing pasture*

B.Equipment list

- 1m quadrat
- Magnifying glass
- Camera
- Pre-prepared data tables and pen
- 4 measuring tapes
- A 50cm ruler

C.Collecting and recording data from fieldwork

1. For a selected area(either fenced or grazing), go to the predetermined coordinates.
2. Place the quadrat on the coordinate.
3. Count the number of different plant species found in the quadrat.
4. Count the total number of individual organisms of a species found in the quadrat.
5. For each plant species identified:
   a) Using the random number generator(1-100), choose a small square within the quadrat. If the species is not present in the square, generate another square.
   b) Randomly choose an individual organism. As it is hard to use a random number generator in this context, make sure to not be as biased as possible.
   c) Using a ruler, measure the height of the plant.
6. For additional information, also count the number of boxes full of plants in each quadrat.
7. Repeat steps 1-6 five times for each sampling attempt.
8. Repeat steps 1-7 for the other study area(whether grazing area or fenced area)

D.Identifying and naming plant species

Species were identified using several sources. Commonly known species such as great burnet were easily identified using websites about the flora of Mongolia. Some species were harder to recognize, therefore I used a species identifier application, a virtual guide and scientific books about the species of Mongolia to increase the precision of identifying. All websites and books used in the identifying process are included in the Bibliography section.

E.Safety precautions and Ethical considerations

Make sure no individual organism is harmed or killed when: measuring their heights with a metal ruler, observing them or placing a quadrat. As plants are relatively frail, handle with care. No organism should be removed. If allergic to plants, make sure to wear a mask to avoid an allergic reaction.

3.Results, analysis and conclusion

Raw data from fieldwork

	Quadrat 1 (1,2)	**Quadrat 2 (7,8)**	**Quadrat 3 (2,1)**	**Quadrat 4 (17,13)**	**Quadrat 5 (6,11)**
Plant species	**total number of individuals (+/-1)**	**total number of individuals (+/-1)**	**total number of individuals (+/-1)**	**total number of individuals (+/-1)**	**total number of individuals (+/-1)**
Western Tansymustard/ Descuainia pinnata	14	8	18	10	12
Crown Vetch/Securigera varia	21	18	15	19	20
Aegopodium alpestre		13	21	17	
Great burnet/Sanguisorba officinalis	27	32	19	22	16
Yellow poppy/Papaver sp.		23		15	20
Greater celandine/ Chelidonium majus	25	31	23	29	18
Cleistogenes	35	32	40	38	35
Meadow crane's-bill/Geranium pratense	17	11	14	20	15
Feather grass/Stipa	47	43	39	45	50
Common silverweed/Argentina anserina	11	8	13	10	11
Smooth brome/Bromus inermis	49	52	45	57	55
Needle grasses	53	60	65	55	59
Pleurospermum uralense		21	15	18	
Allium mongolicum	7	10	5	9	12

Table 1.3 *Number of individuals found for each plant species in each quadrat in fenced area*

	Quadrat 1 (19,1)	**Quadrat 2 (4,18)**	**Quadrat 3 (13,3)**	**Quadrat 4 (6,8)**	**Quadrat 5 (1,15)**
Plant species	**Total number of individuals (+/-1)**	**Total number of individuals (+/-1)**	**Total number of individuals (+/-1)**	**Total number of individuals (+/-1)**	**Total number of individuals (+/-1)**
Milkwhite rock-jasmine/ Androsace lactea	12	6	9	8	
Allium mongolicum		13	9	16	17
Red Fescue/Festuca Rubra	11	22	13	18	20
Centipedegrass/Eremochloa ophiuroides	14	21	11	16	23
Lyme Grass/Leymus Arenarius	15	17	19	12	13
Wild thyme/Thymus serpyllum		15		5	11
Dandelion/ Taraxacum officinale	7	5			4
Cleistogenes squarrosa		11	21	17	19
Needle-leaf Sedge/ Carex duriuscula	20	15	17	9	13

Table 1.4 *Number of individuals found for each plant species in each quadrat in grazing area*

	Quadrat 1 (1,2)	**Quadrat 2 (7,8)**	**Quadrat 3 (2,1)**	**Quadrat 4 (17,13)**	**Quadrat 5 (6,11)**
Plant species	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**
Western Tansymustard/ Descuainia pinnata	20	22	23	19	21
Crown Vetch/securigera varia	24	17	20	18	23
Aegopodium alpestre	29	33	34	32	28
Great burnet/Sanguisorba officinalis	35	37	33	30	34
Yellow poppy/papaver sp.		17		15	19
Greater celandine/ Chelidonium majus	32	36	31	34	27
Cleistogenes	40	35	34	37	37
Meadow crane's-bill/geranium pratense	20	22	18	24	16
Feather grass/stipa	42	39	35	35	40
Common silverweed/Argentina anserina	16	19	18	13	17
Smooth brome/Bromus inermis	37	46	42	36	44
Needle grasses	28	30	34	30	36
Pleurospermum uralense		48	43	39	
Allium mongolicum	18	22	24	19	25

Table 1.5 *Height of individuals found for each plant species in fenced area(rounded to nearest whole **cm**)*

	Quadrat 1 (19,1)	**Quadrat 2 (4,18)**	**Quadrat 3 (13,3)**	**Quadrat 4 (6,8)**	**Quadrat 5 (1,15)**
Plant species	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**	**Height (+/-0.5)**
Milkwhite rock-jasmine/ Androsace lactea	7	10	8	7	
Allium mongolicum		15	11	14	16
Red Fescue/Festuca Rubra	15	10	16	12	11
Centipedegrass (Eremochloa ophiuroides)	14	21	11	16	23
Lyme Grass/Leymus Arenarius	15	17	19	12	13
Wild thyme/Thymus serpyllum		12		10	9
Dandelion/ Taraxacum officinale	9	13			12
Cleistogenes squarrosa		14	11	12	7
Needle-leaf Sedge/ Carex duriuscula	8	9	11	5	9

***Table 1.6** Height of individuals found for each plant species in grazing area(rounded to nearest whole **cm**)*

Error analysis*:* There is a chance I may not have counted every organism, so the number of individuals found for each plant species has an uncertainty of **(+1/-1)**. There might have been systematic errors when measuring the height of each plant, therefore an uncertainty of **(+/-0.5)cm** was used.

Processed data

	Quadrat 1	**Quadrat 2**	**Quadrat 3**	**Quadrat 4**	**Quadrat 5**	**Average**
Total full grids in each quadrat in fenced area (out of 100)	82	89	80	78	83	82
Total full grids in each quadrat in grazing area (out of 100)	72	65	75	69	70	70

Table 1.7 *Total number of full grids in each quadrat in both areas*

Fenced area	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
$D=\frac{N(N-1)}{\sum n(n-1)}$ D=rounded to 3 S.F	$D=\frac{93330}{10802}=8.64$	$D=\frac{130682}{12612}=10.36$	$D=\frac{109892}{11534}=9.53$	$D=\frac{132132}{12584}=10.5$	$D=\frac{104006}{11922}=8.72$

Table 1.8a *Simpson's Diversity Index for plants in the fenced area rounded to 3 s.f*

Grazing area	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
$D=\frac{N(N-1)}{\sum n(n-1)}$ D=rounded to 3 S.F	$D=\frac{6162}{1056}=5.83$	$D=\frac{15500}{1890}=7.82$	$D=\frac{9702}{1444}=6.72$	$D=\frac{10100}{1338}=7.55$	$D=\frac{14280}{1934}=7.38$

Table 1.8b *Simpson's Diversity Index for plants in the grazing area rounded to 3 s.f*

Simpson's Diversity Index is used to quantify species diversity, taking into account the range of species present and the abundance of each species. The formula for Simpson's Diversity Index is $D=\frac{N(N-1)}{\sum n(n-1)}$, where D=Diversity Index, N=total number of organisms found and n=the number of individuals of a particular species.

Type of land	Average Diversity	Standard deviation
Grazing	D=7.06	s=0.79222
Fenced	D=9.55	s=0.87693

***Table 1.9** Average species diversity and standard deviation*

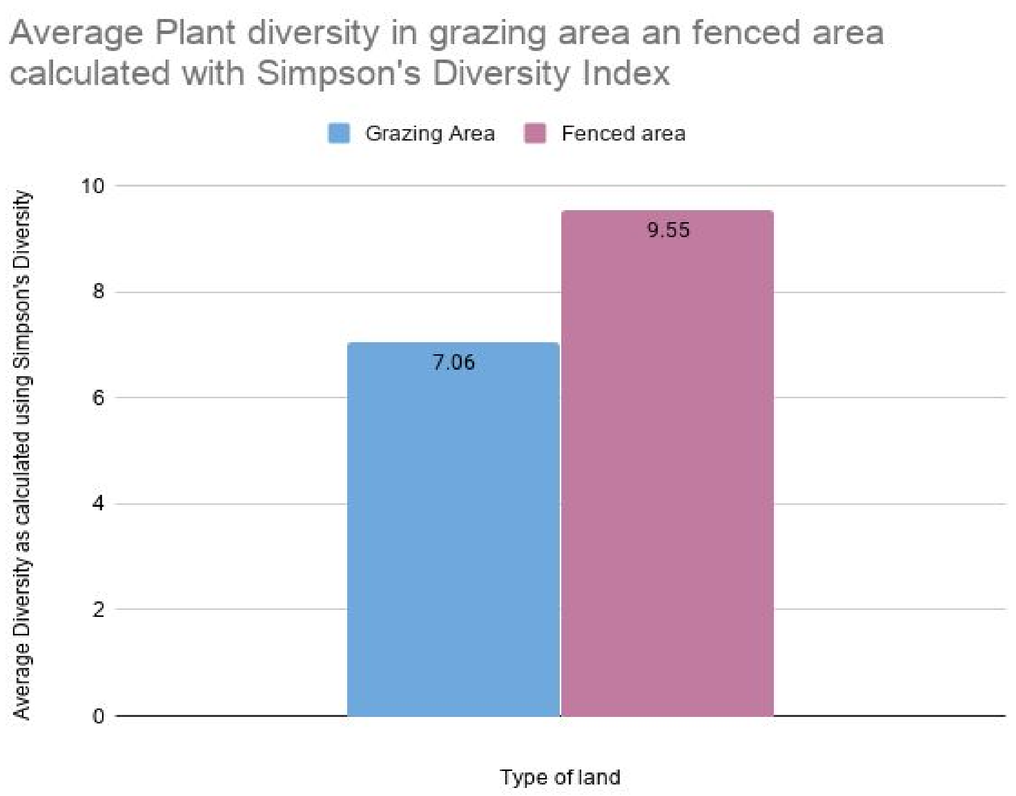

***Figure 3** Bar chart comparing the Average plant diversity in grazing area and fenced area calculated with Simpson's Diversity Index*

T test value	4.7 (rounded to 2 s.f)
Degree of Freedom	8
Critical value	2.3 (rounded to 2 s.f)

***Table 2.1** T-test value for plant diversity in both areas*

I calculated the T-test value to check whether there is a significant difference between the plant diversity in the grazing plains and the fenced area. I proposed a null hypothesis: "there is no significant difference between the plant diversity in both areas." Then in **Excel,** I plugged in the average plant diversity of each sampling attempt in both areas and used the T-test formula to calculate the T-test value. The value of the calculated *T* is bigger than the critical value, **4.7>2.3**. Therefore the null hypothesis can be rejected, implying the observed fieldwork results are not due to sampling error or chance and there is a significant difference between the plant diversity in the two areas sampled.

Plant species	**Average height (+/-0.5)**
Western Tansymustard/ Descuainia pinnata	21
Crown Vetch/securigera varia	20
Aegopodium alpestre	31
Great burnet/Sanguisorba officinalis	34
Yellow poppy/papaver sp.	17
Greater celandine/ Chelidonium majus	32
Cleistogenes	37
Meadow crane's-bill/geranium pratense	20
Feather grass/stipa	38
Common silverweed/Argentina anserina	17
Smooth brome/Bromus inermis	41
Needle grasses	32
Pleurospermum uralense	43

Allium mongolicum	22

Table 2.2 *Average height of each species found in fenced area (rounded to nearest whole* ***cm****)*

Plant species	**Average height (+/-0.5)**
Milkwhite rock-jasmine/ Androsace lactea	8
Allium mongolicum	14
Red Fescue/Festuca Rubra	13
Centipedegrass (Eremochloa ophiuroides)	17
Lyme Grass/Leymus Arenarius	15
Wild thyme/Thymus serpyllum	10
Dandelion/ Taraxacum officinale	11
Cleistogenes squarrosa	11
Needle-leaf Sedge/ Carex duriuscula	8

Table 2.3 *Average height of each species found in grazing area(rounded to nearest whole* ***cm****)*

Height(cm)	Frequency
5-10	0
10-15	0
15-20	2
20-25	4
25-30	0
30-35	4
35-40	2

40-45	2

***Table 2.4** Frequency table of the height of all plant species found in fenced area*

Height(cm)	Frequency
5-10	2
10-15	5
15-20	2
20-25	0
25-30	0
30-35	0
35-40	0
40-45	0

***Table 2.5** Frequency table of the height of all plant species found in grazing area*

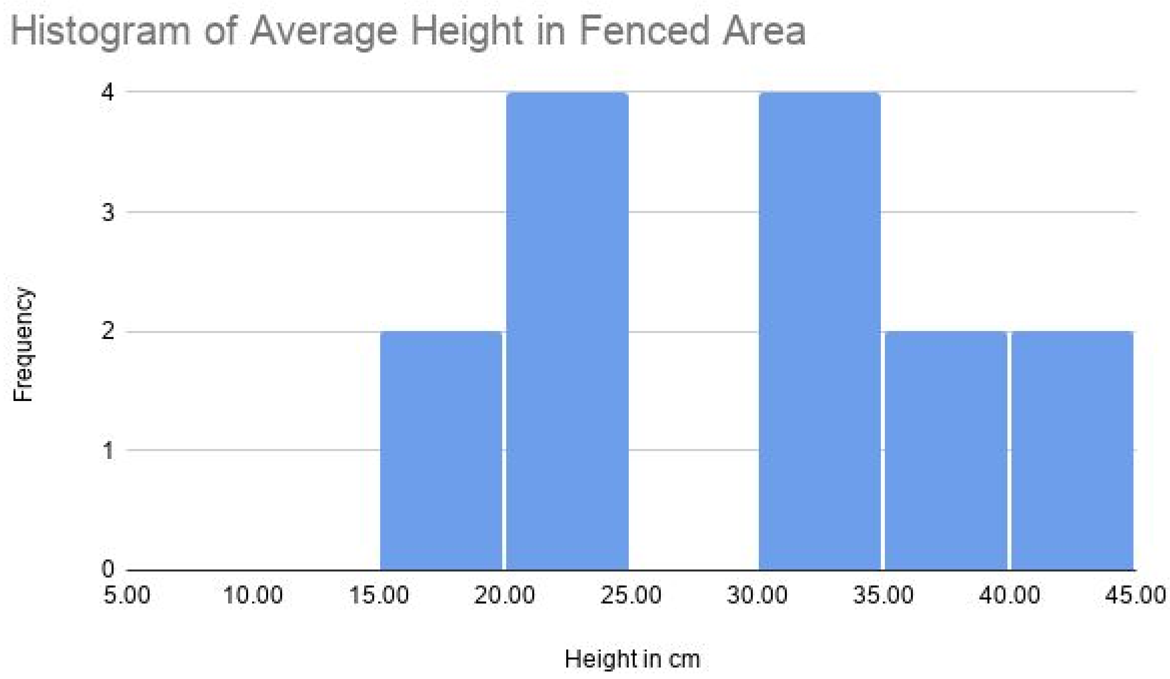

***Figure 4** A histogram showing the height frequency of plants in fenced area*

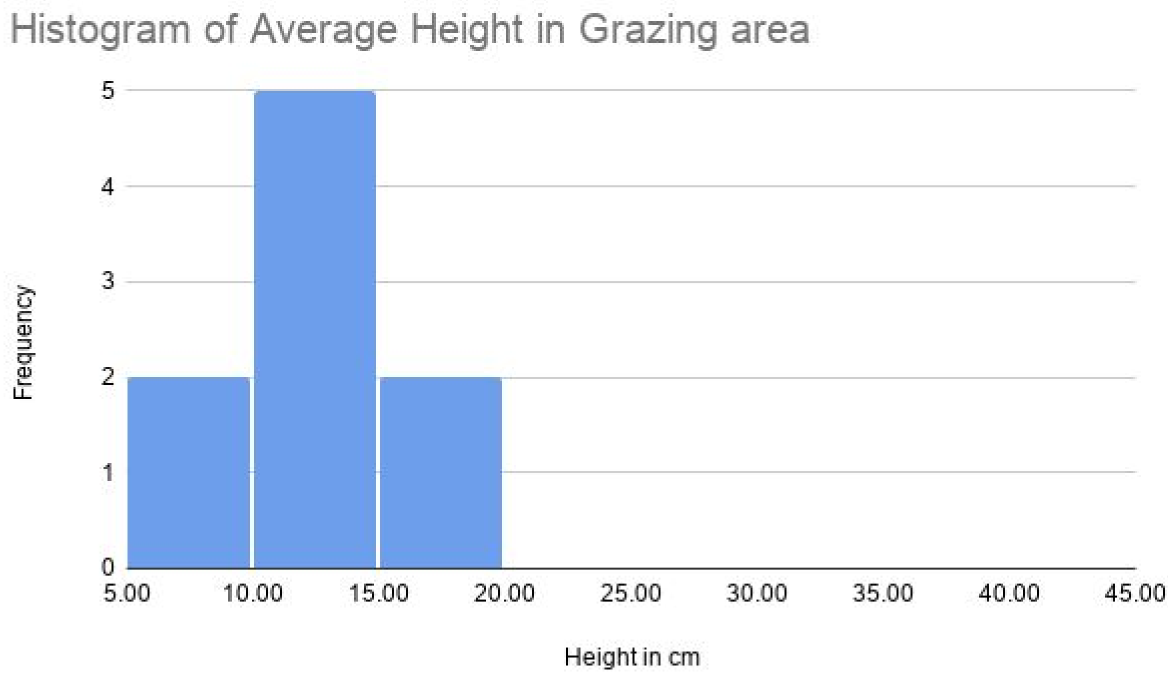

Figure 5 *A histogram showing the height frequency of plants in grazing area*

<u>Conclusion</u>

From tables 1.8b and 1.9, as well as figure 2, it can be seen that a greater plant diversity is present in the fenced area. Data from table 1.7 represents a denser vegetation cover in the fenced area, as the ratio of average total number of full grids is 82 to 70. Tables 2.4 and 2.5, along with figures **3** and **4** show that plants grow comparatively taller in the fenced area, as the average height of species prevails between 20-35cm compared to 10-15cm of the grazing pasture. From these data, it can be concluded that the grazing area has lower plant diversity and vegetation cover. The average height of the species is low because cattle actively graze there, removing a significant portion of the flora. These essentially indicate a lower soil productivity. The data collected shows that intensive grazing does reduce soil productivity and vegetation cover.

4. Discussion and evaluation

Strengths, Weaknesses and Limitations:
The research question seeks to investigate soil productivity. One limitation of this fieldwork is that I assumed soil productivity is mainly represented through plant diversity and vegetation cover. This could be improved by measuring other components of soil such as pH, compaction levels, moisture or nutrient content. Another possible weakness is when counting the total small squares full of plants, I may not have accurately deduced whether a grid is full or not as it is a relatively objective indicator. This could have been improved by repeating the step multiple times and finding the average.
A strength of this fieldwork would be that it allowed unbiased random investigation to take place, as I used a random number generator to choose the coordinates for my target area. This investigation is also designed in an easily repeatable way.

5.Applications

Suggested solution to the environmental issue
One possible solution to decreased plant diversity and soil productivity due to overgrazing is rotational grazing, meaning farmers move their livestock through different parts of the pasture. In the context of the Terelj grazing pasture, the local cattle grazing focused in one area. The local farmers can create a rotational grazing system where only one portion of the pasture is grazed at a time while the remainder of the pasture "rests".[3] This practice prevents overgrazing, as cattle "do not have a chance to regraze new growth of their preferred forages, which both weakens the plant and contributes to the formation of lawns and bare spots."[4] Rotational grazing gives pastures time to recover from grazing

Evaluating the solution
The solution is potentially effective because it would be easy for local farmers to practice rotational grazing due to their nomadic lifestyle. This solution would also allow to keep pastures more productive in the long term. It would also keep pasture more productive over the long term. However, it could be inefficient for locals to move around the livestock so much as it requires a lot of time and monitoring and may reduce economic production. The solution also requires a very specific rotational plan to be followed by all locals, making it difficult to implement and monitor.

[3] "Pastures for Profit: A Guide to Rotational Grazing (A3529).". https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097378.pdf.
[4] Paul Sharpe, Laura B. Kenny. *Horse Pasture Management*. Academic Press. 2019

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[5] This is a report on the degree of desertification by the Ministry of Environment and Tourism of Mongolia.