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A landscape approach to water storage/harvesting - Key outputs target: 4.01; (4.06); 2.16; 4.15

Suitability mapping of several sustainable land management practices (SLMs) in Uzbekistan

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Introduction

Drylands cover more than 47% of the global land surface and consist of dry sub-humid, semi-arid, arid, and hyper-arid regions. Large parts of these drylands are at risk or are currently experiencing land degradation due to an extensive list of causes, such as intensive exploitation of natural resources, land mismanagement, or the impacts of climate change (Reynolds et al., 2007). Land degradation has impacted local ecosystems, resulting in soil crusting and reduced infiltration. This has the effect that vegetation cover decreases even more and cannot regrow as quickly in the areas affected (Tatsumi et al., 2021). As a result, the primary function of these drylands of being grazing areas for livestock can no longer be fulfilled, and this has enormous impacts on local communities that rely on this.

Sustainable land management (SLM) practices can be used to combat this degradation of drylands. The SLMs can be done in several ways, either by preventing further degradation or rehabilitating already degraded soils.

In Jordan, the International Centre for Agricultural Research in Dry Areas (ICARDA) has been involved in ecosystem restoration projects in the Jordanian Badia, a vast arid - semi-arid region found in the Middle East, and tested and evaluated some of these methods. One of the methods tested is constructing the mechanized micro water harvesting technique (MIRWH), locally known as Vallerani. The Vallerani consists of plowing a furrow and a ridge on a gentle hillslope to increase the infiltration of water. When small shrubs are added to the furrow, soil moisture retention is increased, improving biophysical properties in the soil and decreasing soil erosion (Karrou et al., 2011). The effectiveness of these structures depends on the amount of rainfall; as little as 100mm a year can support these structures. However, too much precipitation might cause the filling of the structures with sediment too quickly.

Figure 1: left: "Vallerani" system as implemented by ICARDA in Jordan, right: the same system after a year (source: ICARDA)

Another technology developed is the Marab, a larger-scale structure designed to capture and retain rainwater flowing as discharge. The Marab can be employed in the flat downstream part of the catchment of about 10 km^2, where water would generally spill away. Instead, by constructing small dams and leveling of soil, surface runoff is reduced and preferential flow, i.e., flowing through smaller drainage networks. Additionally, the Marab has the effect that more water is retained in the region, and thus more water is available for infiltration into the soil, which can, in the case of the experiment location in Jordan, result in more extensive agriculture to function as fodder for livestock (WOCAT, 2017.)

A third method considered for this model study is the usage of Saxaul bushes to reduce wind erosion. These so-called Saxaul tree plantations (abbreviated STP) are planted in flat areas on denuded sandy soils to stabilize the soils, and this method uses plants local to Central Asia. A project by ICARDA was carried out in the southwest of Tajikistan, and 25 ha of Saxaul tree plantations were created over two years. The plants are planted in parallel rows with 15 m between them, and if protected against grazing, will increase water infiltration, reduce soil degradation, and increase local biodiversity (WOCAT, 2017.)

Using multiple SLMs in one region can be helpful for total land rehabilitation, for example, using Vallerani structures on hillslopes and Marab structures in the flat lands downhill. To this end, this study will also look at combining the three SLMs. Even though they are not used at precisely the exact location, within one grid size, multiple SLMs can exist.

The implementation of the abovementioned SLMs has shown promising results, and the objective of the ICARDA project is to indicate more areas where these methods will work and can help in rangeland rehabilitation. This report aims to show where sustainable land management practices can be implemented in Uzbekistan.

Methods

This section is divided into multiple parts. The first part regards the criteria used for identifying suitability. The second part explains how the model works, and the last part shows which datasets were used and why they were selected.

Criteria for the usage of sustainable land management practices

To identify where certain practices can be implemented, it is necessary to identify the criteria required to implement an SLM practice successfully. In this case, as was chosen for Vallerani, Marab structures and the Saxaul tree plantations will have to be quantified. As the introduction outlines, Vallerani structures are in locations with hills, whereas Marabs are in low-lying floodplains. The Saxaul tree plantations also do work best in flat areas. All of the site-specific characteristics are reflected in the criteria. The sand, rock, and clay content determine the suitable soil types. These parameters were determined in experimental settings, collected by WOCAT, and presented in table 1.

Table 1: Criteria for selected SLMs and the ranges used in the suitability modelling

Sustainable land management practice	*Criteria*	*Ranges*
Vallerani	Land use/cover	Bare area, sparse vegetation
	Sand %	≤ 50
	Stone %	≤ 20
	Clay %	≤ 50
	Soil depth cm	≥ 50
	Slope %	≤ 30
	Rainfall mm	100 ≤ rainfall ≤ 300
Marab	Land use/cover	Bare area, sparse vegetation
	Sand %	≥ 50
	Stone %	≤ 20
	Clay %	x
	Soil depth cm	≥ 100
	Slope %	≤ 1.5
	Rainfall mm	≥ 100

Sustainable land management practice	*Criteria*	*Ranges*
Saxaul tree plantation	Land use/cover	Pasture, Forest
	Sand %	≥ 50
	Stone %	x
	Clay %	x
	Soil depth cm	80 ≤ soil depth ≤ 120
	Slope %	≤ 2
	Rainfall mm	≤ 250

Methodology of the suitability mapping

The mapping was conducted in the framework of the Google Earth Engine. In short, the model evaluated for each biophysical parameter whether a pixel was suitable for the selected Sustainable Land Management practices. The biophysical layers' information and their suitability were summed up. And if the location was within the boundaries of table 1, this was marked as suitable for the LSM. If one of the parameters did not correspond to the boundaries set in table 1, then the location was marked as unsuitable for the LSM. Pixel size was determined by data availability.

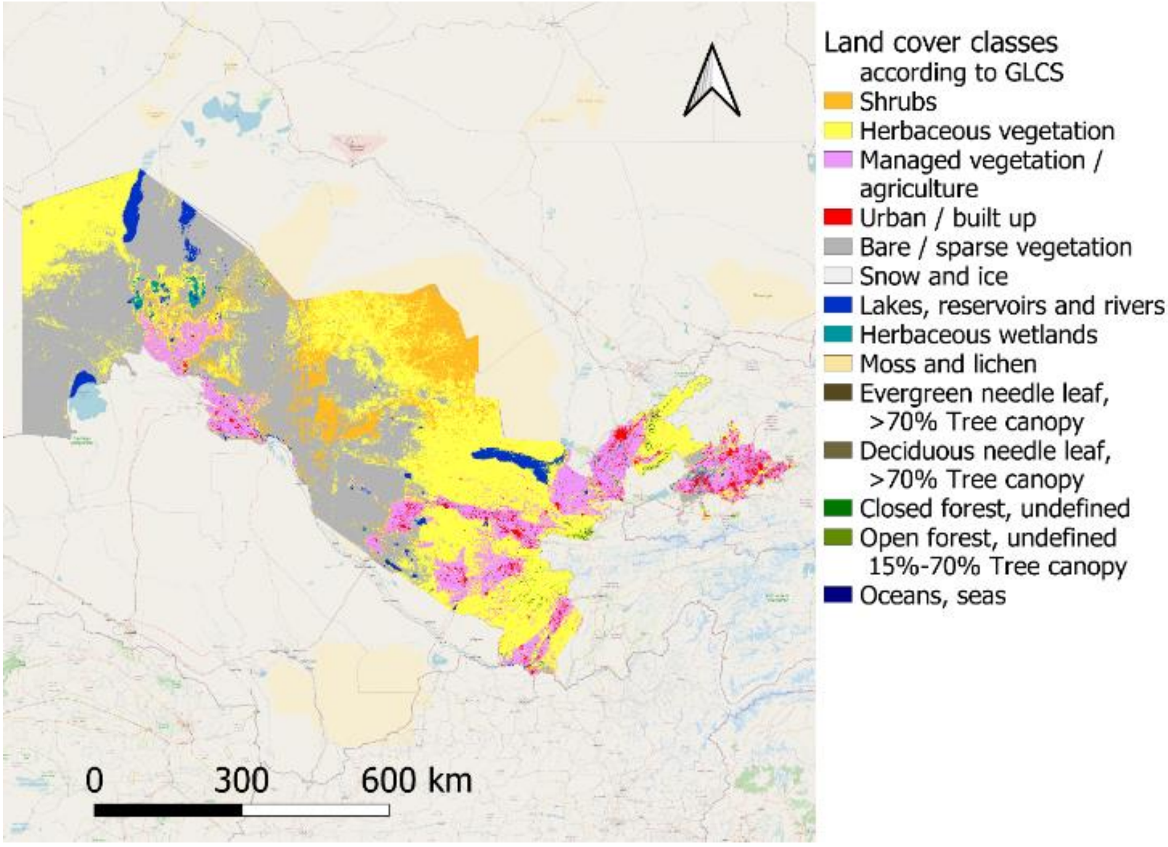
The most extreme limits were taken to test the suitability of multiple SLMs simultaneously. For example, we take the combination of Marab and Saxaul tree plantations. Here the rainfall limits will be more than 100 mm and less than 250 mm. The rest of the methods were the same for determining a single SLM's suitability.

Datasets

The datasets used for the suitability mapping are presented in table 2. The resolution of the map shows the original resolution used in the model. However, the lowest resolution of 0.05° was chosen for the final resolution. The original data for the datasets chosen is a mix of satellite and ground-based data. This way, the best datasets were chosen to describe the various required criteria accurately.

Table 2: an overview of the datasets used in the suitability modelling

Dataset name	Criteria in dataset	Resolution	Source	Website
Copernicus (CGLS)	Land use/cover	100m	(Buchhorn et al., 2020)	https://land.copernicus.eu/global/lcviewer
SoilGrids	Sand % Rock % Clay % Soil depth (cm)	250m	(Poggio et al., 2021)	https://files.isric.org/soilgrids
CHIRPS	Rainfall (mm)	5566m (0.05°)	(Funk et al., 2015)	https://www.chc.ucsb.edu/data
SRTM	Elevation (m) Slope	30m (1 arcsecond)	(Farr et al., 2007)	https://www.usgs.gov/centers/eros



Land cover data

Copernicus Global Land Service (CGLS) has made a 100m Land Cover map with high accuracy for the reference year 2015; it shows more than 80% accuracy for all continents when validated (Buchhorn et al., 2020). This data is used to identify which regions of the land cover units are suitable for the different SLMs, as presented in **Error! Reference source not found.**.

Figure 2: Land cover classes used (Buchhorn et al., 2020)

Soil data

SoilGrids is a high-resolution global soil map, which maps soil type, physical soil characteristics, chemical soil characteristics, and some derived properties such as organic content at a 250m resolution. The dataset is a result of 240 000 soil observations and 400 covariates, which uses machine learning to map the global distribution of the characteristics. The data is available for six soil layers up to 2m depth, but for the suitability mapping, only the top layer (0-5cm) is used as we are concerned with surface processes (Poggio et al., 2021). Various parameters are extracted from Soil Grids for the suitability mapping, as shown in Table 2. An example of one of the datasets extracted from the SoilGrids dataset is the bedrock depth, as displayed in figure 3. The data is shown in figures 3 to 6.

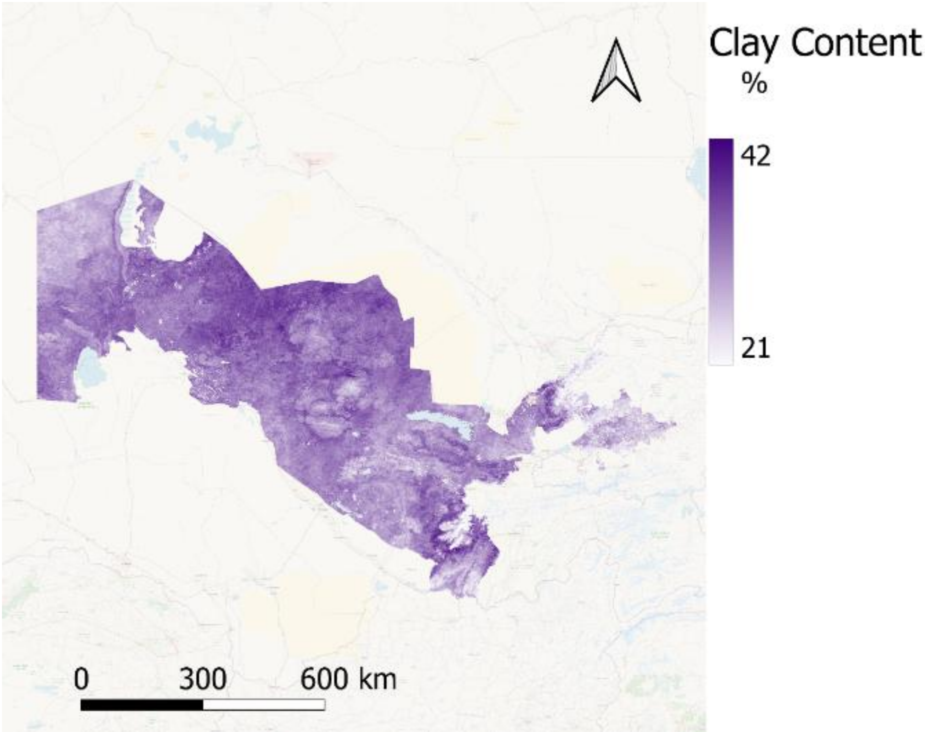


Figure 3: Clay content of the top soil layer (Poggio et al., 2021)

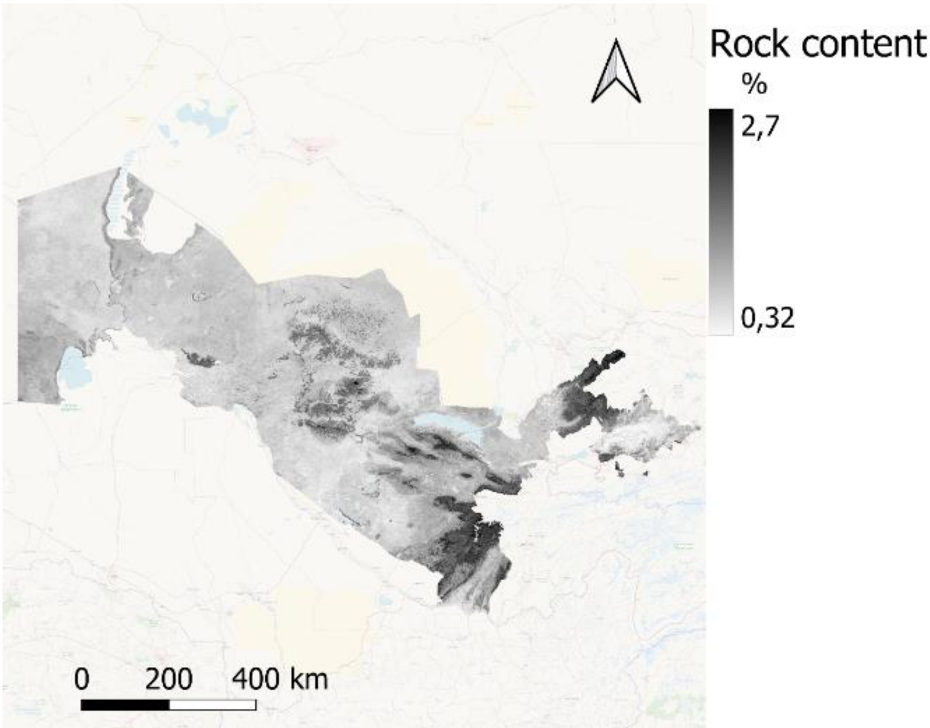


Figure 4: Rock content of the top soil layer (Poggio et al., 2021)

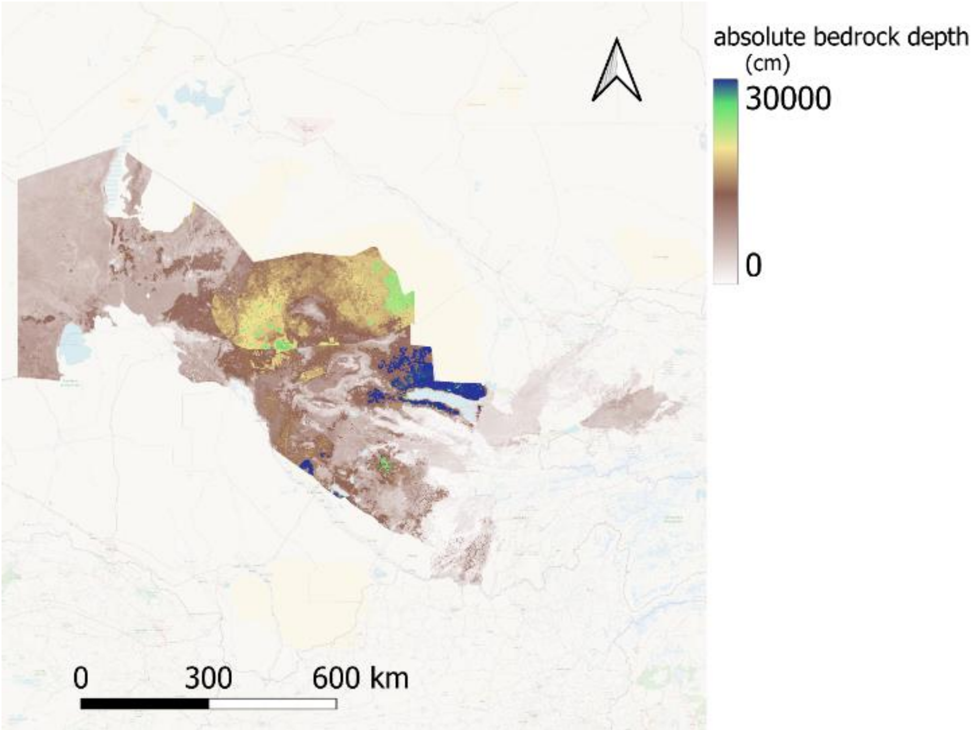


*Figure 5: Sand content of top soil layer (*Poggio et al., 2021)

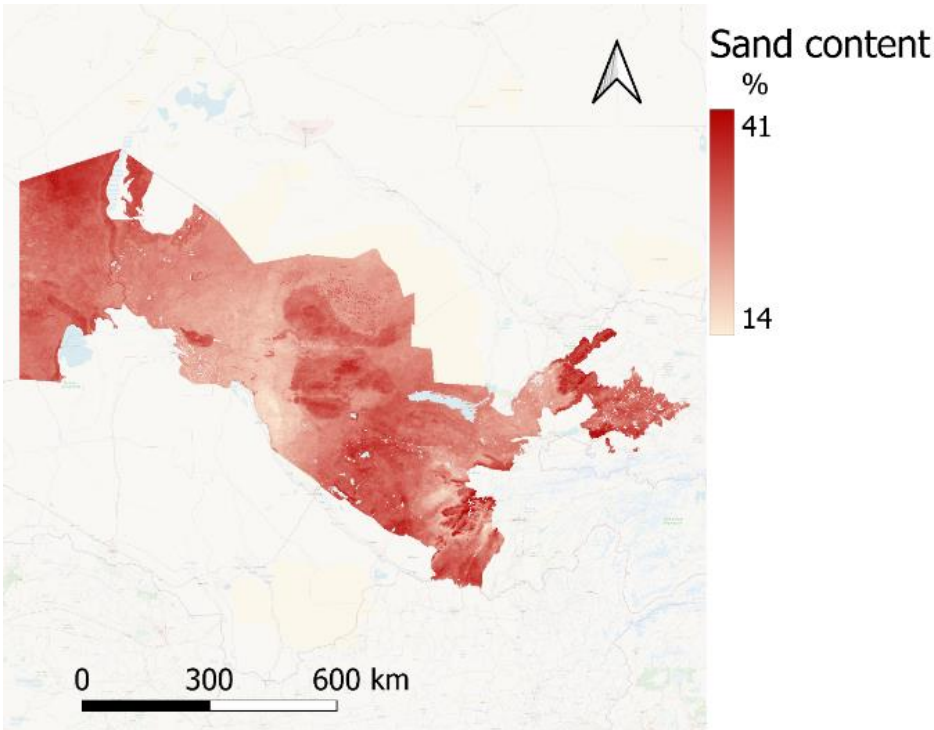


Figure 6: : Bedrock depth from SoilGrids (Poggio et al., 2021)

Rainfall data

Water availability is an essential factor for many of the SLMs considered. For this reason, a suitable dataset for rainfall is needed, as this is the world's primary water provider. The CHRIPS (The Climate

Hazards group Infrared Precipitation with Station) dataset was chosen to map the rainfall suitability. This dataset combines local gauging station data with satellite observations in a model to provide monthly precipitation data of reasonably high quality for even data-scarce regions (Funk et al., 2015). This high-resolution dataset provides a clear image of the yearly precipitation over Uzbekistan, showing expected rainfall patterns as shown in figure 7.

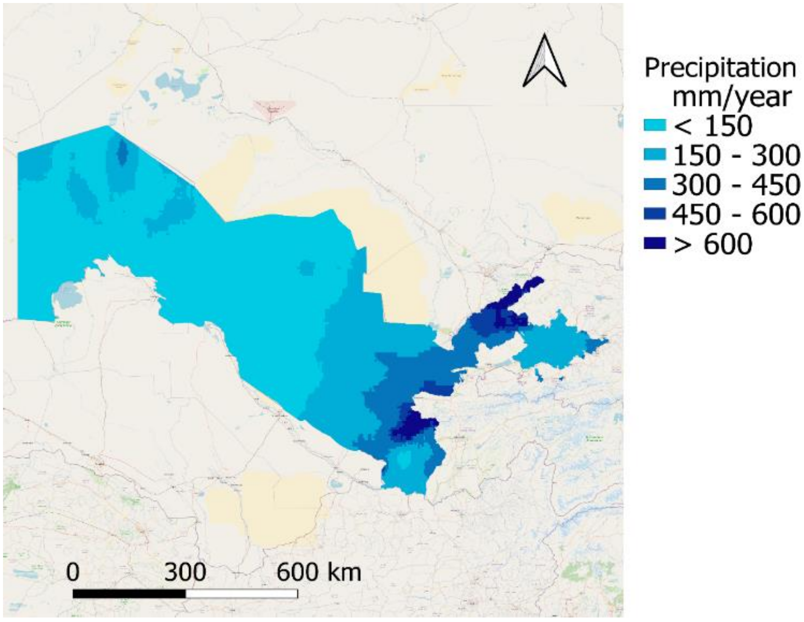


Figure 7: Annual precipitation from CHIRPS (Funks, et al., 2015)

Elevation data

The elevation data and the data used to calculate the slope were gathered from the SRTM (Shuttle Radar Topography Mission) dataset. This dataset was made using a space shuttle satellite to gather high-resolution topographic data (Farr et al., 2007). The resulting slopes and elevation are presented in figure 8.

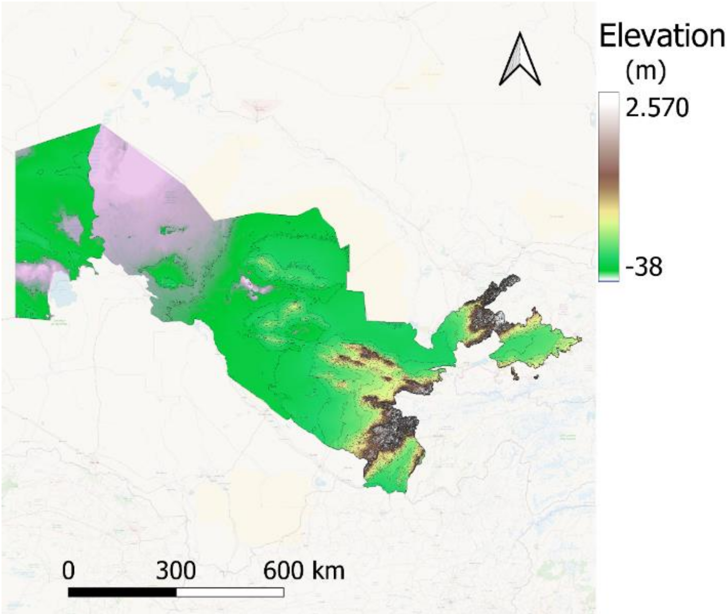


Figure 8: Elevation data in Uzbekistan from SRTM (Farr et al., 2007)

Results

The results of the suitability mapping of the different SLMS are presented here in three maps indicating the suitability of the different regions for the considered areas. Red indicates unsuitable locations, and green indicates suitable locations. No colored areas are not considered as they lack relevant data for the suitability analysis. Absolute areas are presented in table 3 and compared to the total land area of Uzbekistan of 447.400 km^2. The total areas suitable for the different SLMs are extensive, ranging from 47 to 62% of the total land area of Uzbekistan.

The suitability is measured for each criterion for the three different SLMs and mapped; these maps can be found in the Appendix. In general, the eastern areas of Uzbekistan are less suited for the chosen SLMs, mainly due to high elevations and rock content, and the north, center, and west generally have high suitability for the chosen SLMs.

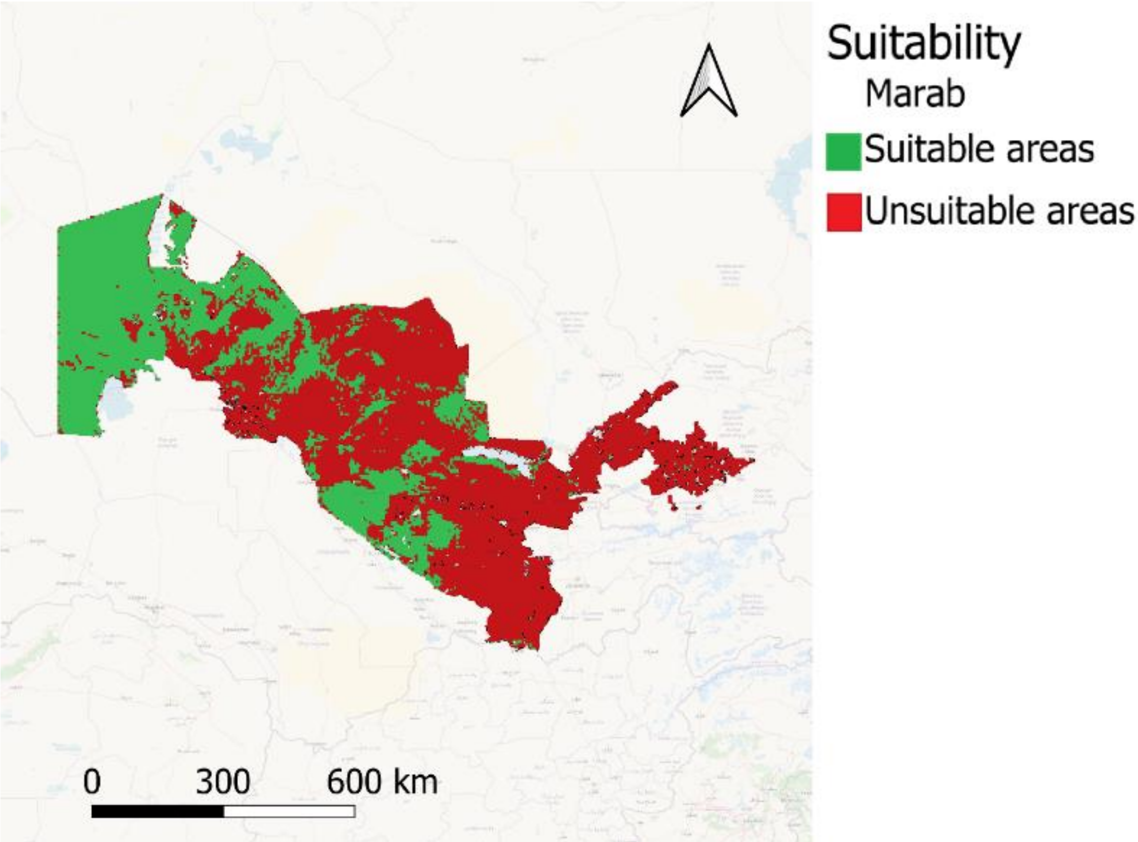


Figure 9: Suitability of Marab technology in Uzbekistan

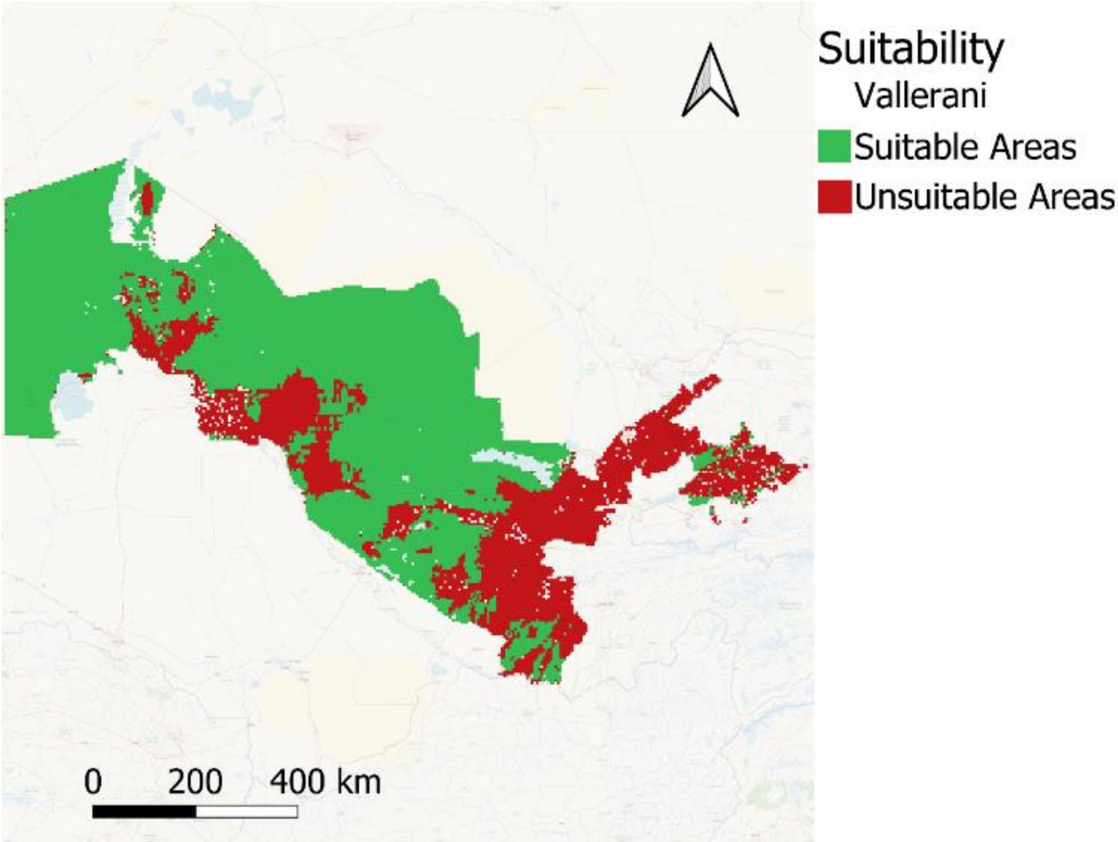


Figure 11: Suitability of Vallerani technology in Uzbekistan

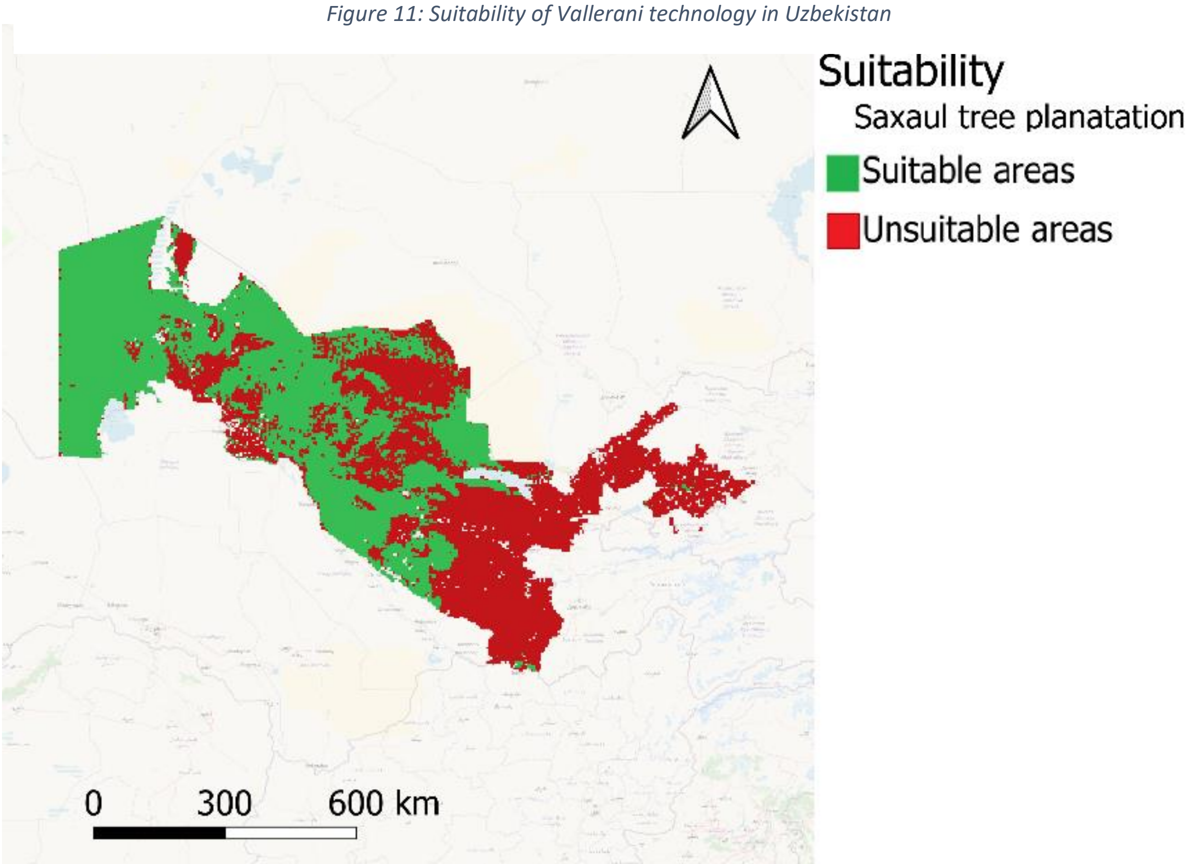


Figure 10: Suitability of Saxaul tree plantation technology Uzbekistan

Table 3: reported suitable or unsuitable areas for SLMs

SLM practice	Suitable land area	Unsuitable land area	% of total land area
Vallerani	278.747 km²	144.604 km²	62%
Marab	204.191 km²	219.160 km²	47%
Saxaul tree plantation	232.862 km²	190.418 km²	52%

Combination of SLMs

For an integrated land rehabilitation strategy, several SLMs can be combined. To this end, maps were created to show the suitability of combinations of the three SLMs. These results are shown in figures 12 to 15, and the areas are reported in table 4.

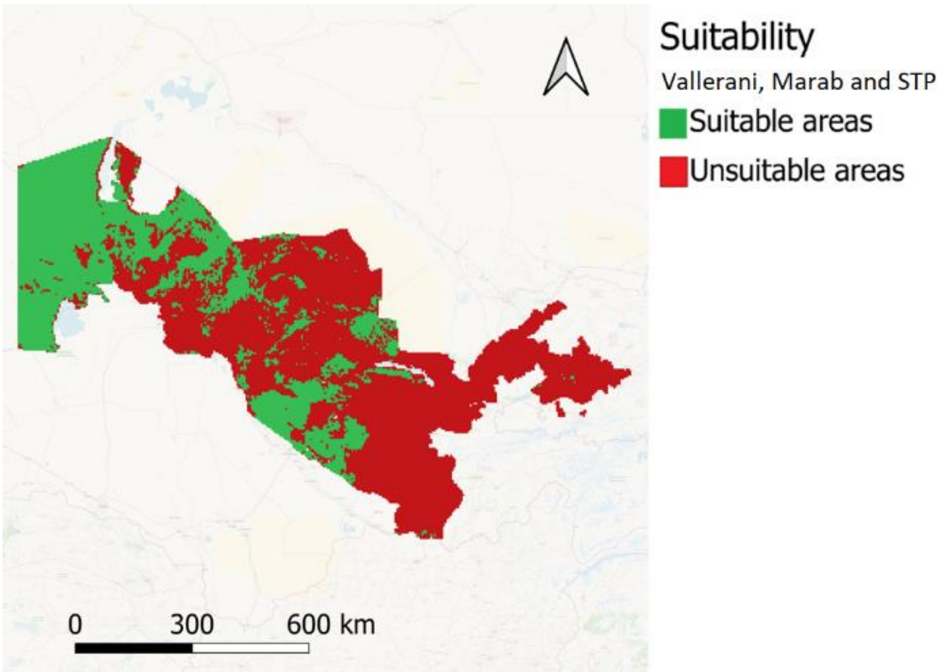


Figure 12: Combined suitability of Vallerani Marab and Saxaul tree plantation in Uzbekistan

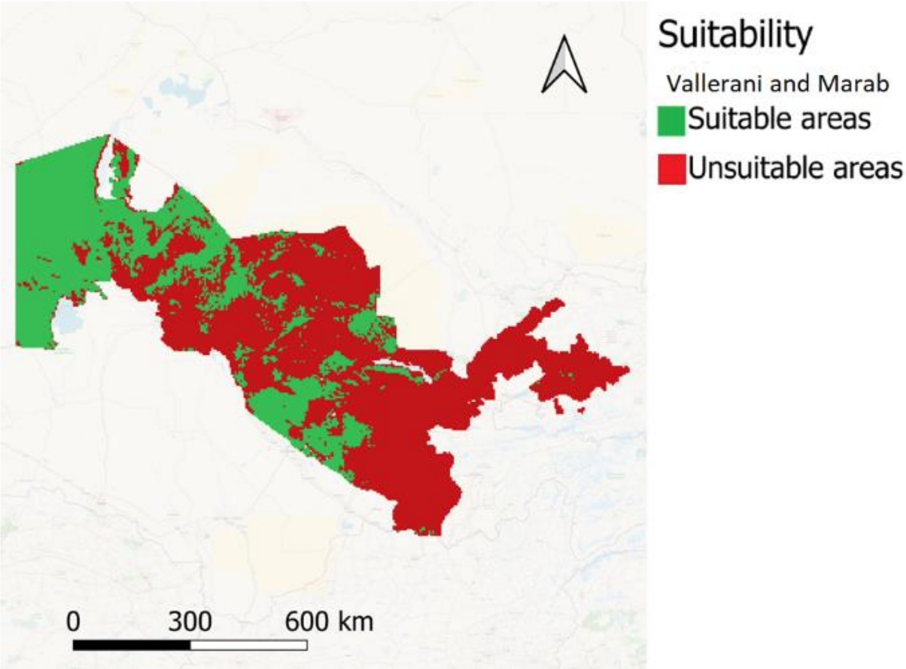


Figure 13: Combined suitability of Vallerani and Marab in Uzbekistan

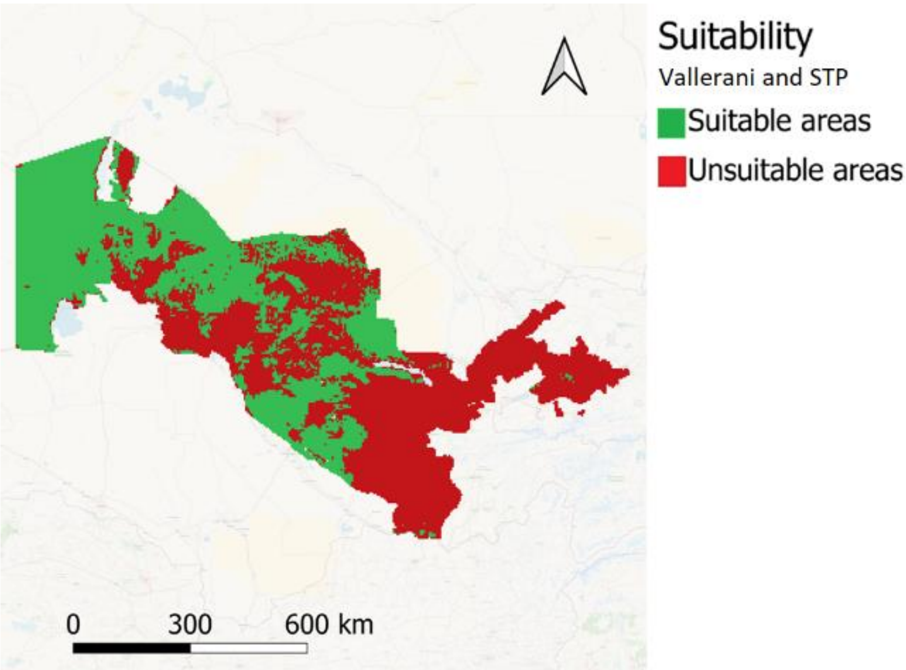


Figure 14: Combined suitability of Vallerani and Saxaul tree plantation in Uzbekistan

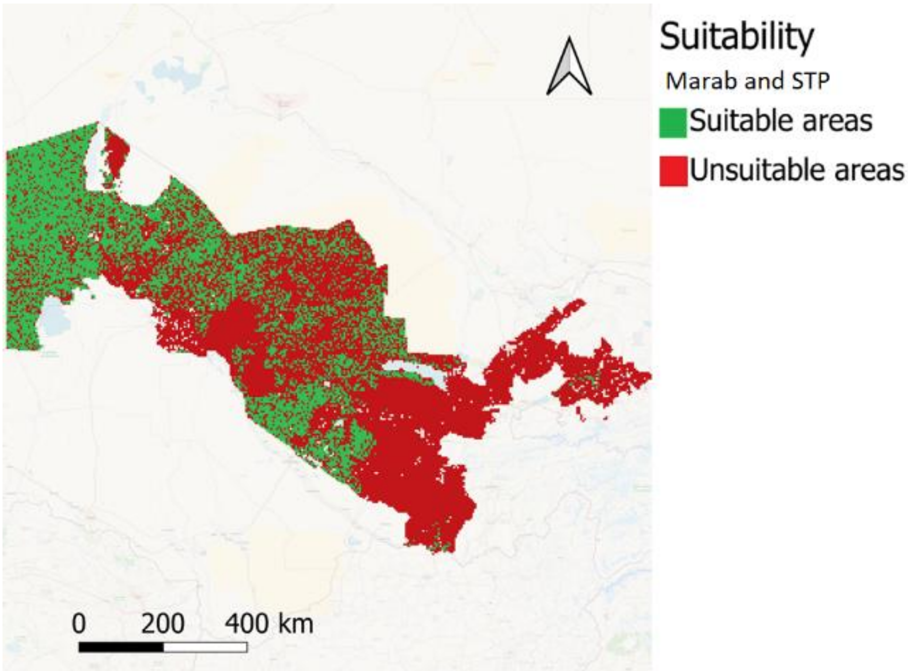


Figure 15: Combined suitability of Marab and Saxaul tree plantations in Uzbekistan

Table 4: reported suitable or unsuitable areas for combined SLMs

SLM practice	Suitable land area	Unsuitable land area	% of total land area
Vallerani + Marab+ STP	195.449 km²	227.863 km²	44%
Vallerani + Marab	201.361 km²	221.990 km²	45%
Vallerani + STP	214.567 km²	208.742 km²	48%
Marab + STP	195.449 km²	227.863 km²	44%

Discussion

The suitability of the 3 SLMs is highest in the west and generally lower in the east. The reason is that all SLMs considered are better suited to flatter areas, especially the Marab and Saxaul tree plantations. Even though the Vallerani method can be used in hilly areas, the east of Uzbekistan is too steep to implement this method. Another explanation for the same regions generally being unsuitable for the SLMs is the land cover of these areas. In particular, the urban regions and the regions already under intensive cultivation are all unsuitable for the practices considered. The areas already under cultivation are generally also not areas that benefit from SLMs, as these areas are already productive. The main reasons for areas being considered suitable or unsuitable are Land cover classes and rainfall, followed by slope and elevation, as seen in the figures in the Appendix.

Comparing the suitability maps of the Marab and the Saxaul tree plantations shows a slight difference between the hillslopes in the north of Uzbekistan, where slightly more suitable land is available for the Saxaul tree plantations than for the Marab. However, the two SLMs show similar spatial patterns owing to their similar biophysical criteria.

Implementation of Vallerani is suitable for large parts of Uzbekistan, especially in the drier regions of the center and west of Uzbekistan, as the Vallerani method is limited to 300mm annual precipitation to prevent too much soil erosion from filling the furrows too rapidly.

The figures and reported areas for the combined SLMs showed no new information as they were combinations of the earlier figures. In general, the suitable area was smaller than for the single SLMs. Here it can be noted that the usage of Vallerani does not influence the suitable area r, as the area for the Marab and Saxaul tree plantations is the same as when Vallerani and those two other SLMs. The Marab technology is the most limiting, resulting in the lowest total area. However, the total suitable area for the combined method is still higher than 40% for all combinations.

In general, soil type (clay%, rock%, and sand%) does not play an essential role in determining a suitable location. This is likely due to the broad range of these chosen soil criteria. Detailed data on soil types where the SLMs are suited is needed to identify soil criteria better. Taking Saxaul tree plantations as an example, the soil criteria provided by WOCAT (2017) only indicate that soil type should be coarse and sandy, whereas Matinkhah et al. (2016) cite different soil conditions, as shown in Table 5. However, when using this data to calculate the area with GEE, it yielded no suitable areas for Saxaul tree plantations to work in Uzbekistan. It was discarded, as the location that WOCAT used was similar to some sites in Uzbekistan, and the criteria used by Matinkhah et al. (2016) were probably too harsh or too dependent on the one plant species they used. The discrepancy in soil data between different experiments shows that this is an area where data availability for the criteria needed to succeed in implementing an SLM is limited.

Table 5: Criteria and ranges for Saxaul tree plantation according to Matinkhah et al. (2016)

Criteria	Range
Clay %	0-25
Sand %	40-95
Gravel %	0-50
Annual rainfall	>160mm

The ranges in table 5 resulted in no area being suitable for Saxaul tree plantation, but this was due to the clay fraction, as this was the main reason for the unsuitability. Matinkhah et al. (2016) showed the optimal growth conditions for Saxaul tree plantation, which also had a different rainfall requirement. A run was performed where the clay fraction was disregarded to see the effects, more refined sand and clay fraction requirements, and the optimal rainfall requirements. The results of this did show some areas being suitable for the method. This resulted in a suitable area of 41.408 km^2, five times lower than the initial area determined. However, as this study was for optimal growth, this does not rule out that the earlier result is wrong, just that it might not have optimal growth of the Saxaul tree plantations. For a follow-up study, if better data is available, optimal and extreme ranges for the SLMs are identified and used to calculate the area suitable for these SLMs separately.

The model does not consider the area around the former Aral Sea. This results in this area being left as ‘blank’ even though this area might be interesting for potential SLMs. This is due to the SoilGrids dataset, which does not have data for this region. If one layer of data does not have the data required, the area is ignored for the suitability calculations. This shows the importance of high-quality and up-to-date input data. Even though SoilGrids is one of the most advanced soil data products that can be used at the time.

The results of the current modelling exercise are only a broad overview of possible locations as determined by several datasets. Local conditions may vary from this as the grid size of the results is 0.05°, which is still a large area of about 5500m by 5500m. So, the results here are a good first indication, not a definitive result.

Conclusion

Implementation of SLMs is highly dependent on the biophysical criteria of the practices to be considered. SLMs suitable for more varied biophysical criteria will also be able to be implemented in more cases. High-quality input data is needed and is often available, although rainfall data remains the lowest resolution. A part that needs to be added is the ranges at which some of the SLMs operate best, as was outlined by looking at the different ranges for the criteria for the Saxaul tree plantations. However, even though some information is contractionary, the results can be used to give a first insight into where the SLMs can be used.

The results showed that the Vallerani method could be used to the most considerable extent in Uzbekistan for 62% of the land area, followed by the Saxaul tree plantations at 52% and the Marab at 47%. This is a large extent for all methods and thus shows that the 3 SLMs considered here could potentially be used in Uzbekistan.

A combination of the methods is possible and is limited by the narrowest ranges. However, the total available area is still significant, with 45% of the surface area of Uzbekistan being suitable for using Vallerani, Marab, and Saxaul tree plantations together.

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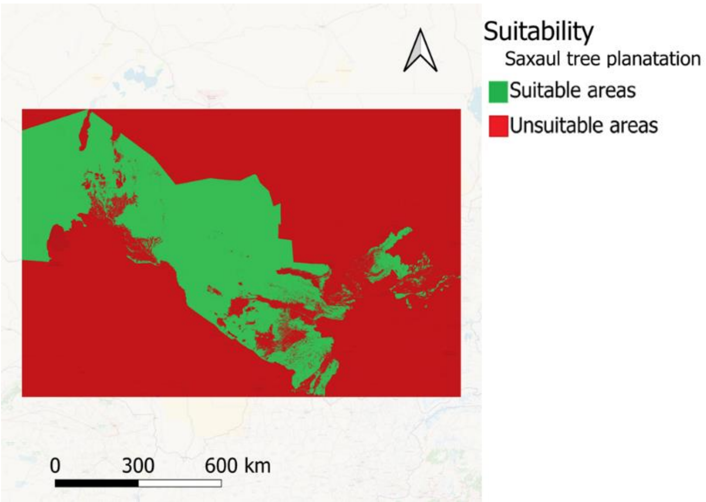
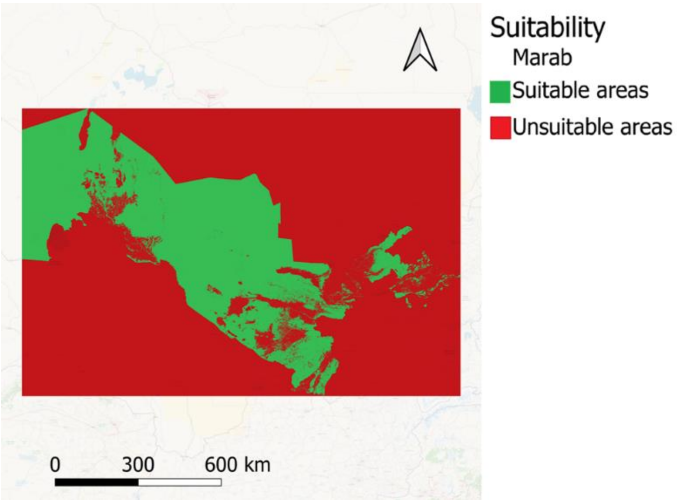
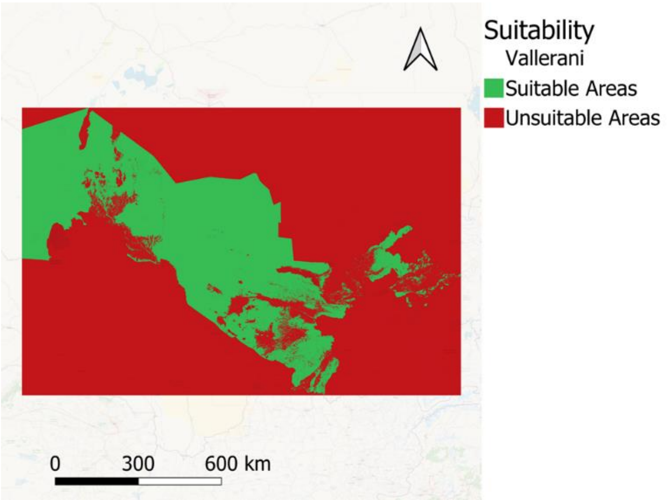
Appendix

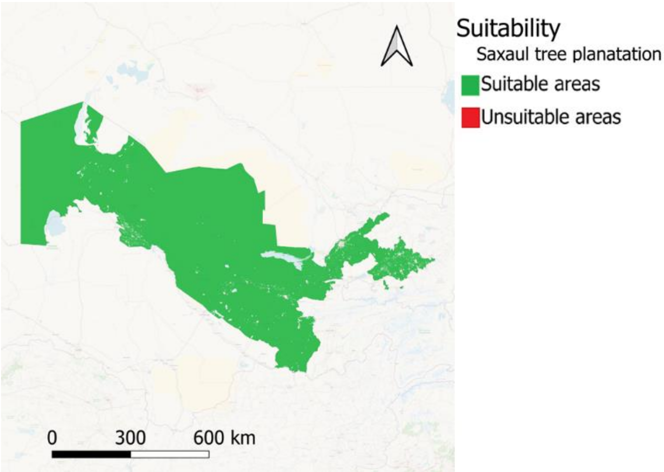
Appendix A: Land cover suitability for the three different SLMs.

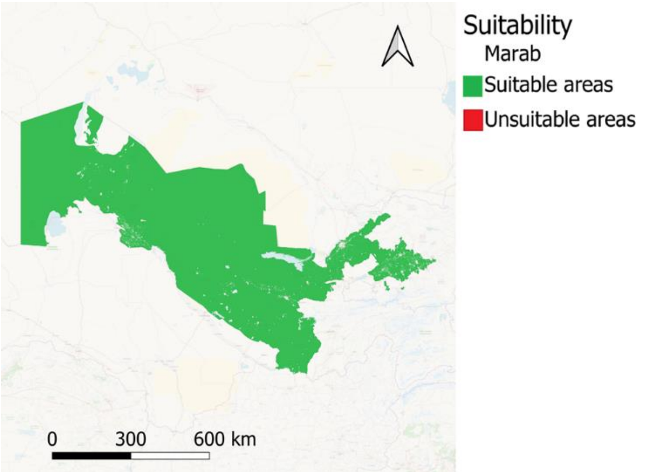


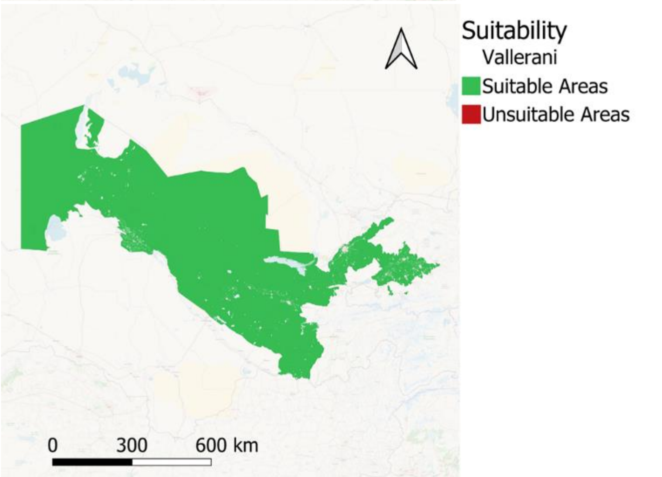




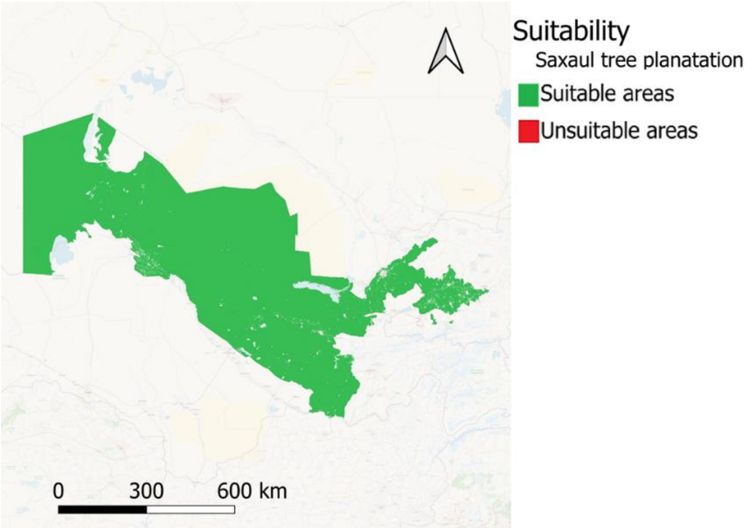
Appendix B: Sand percentage suitability for the three different SLMs.

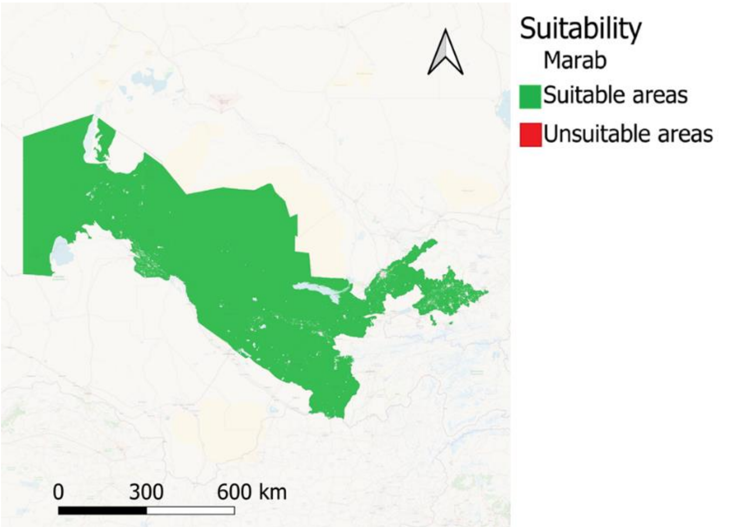


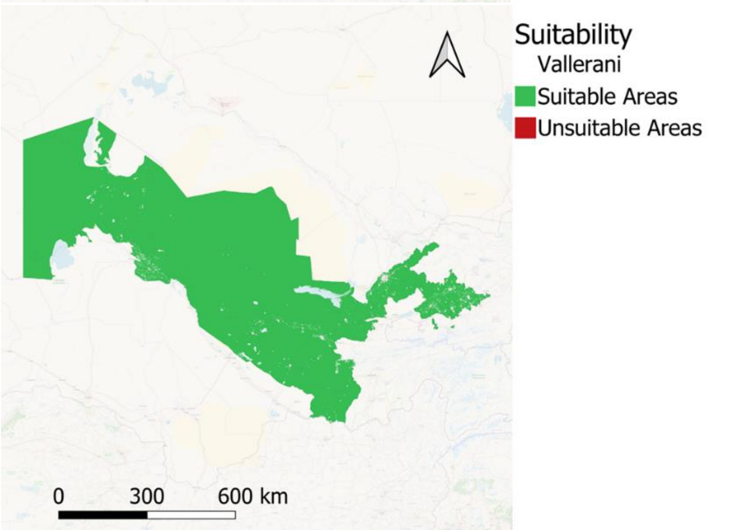




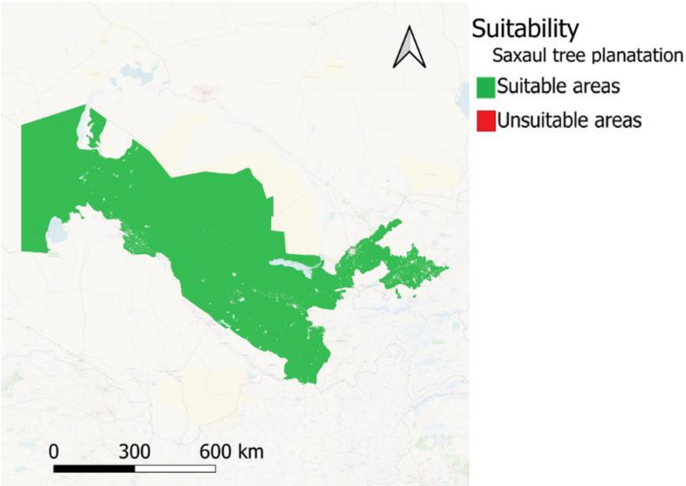
Appendix C: Stone fraction suitability for the three different SLMs

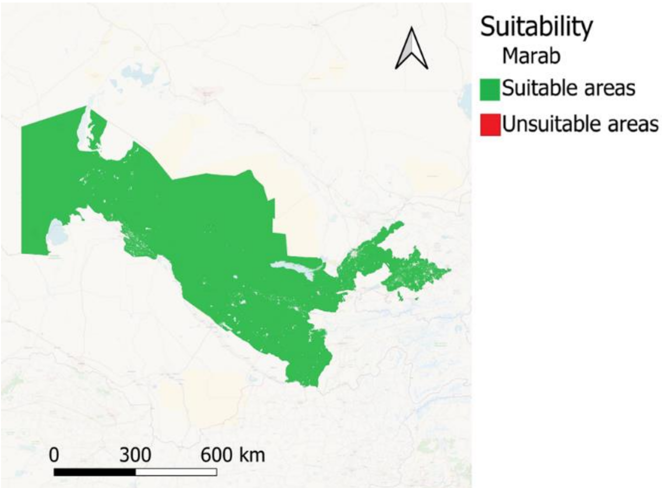


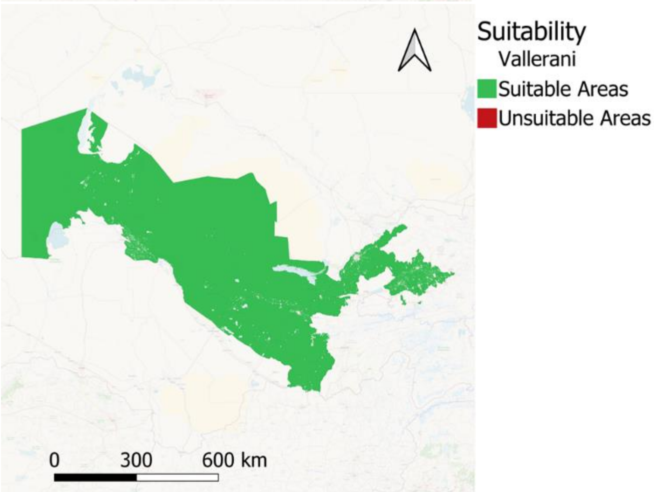




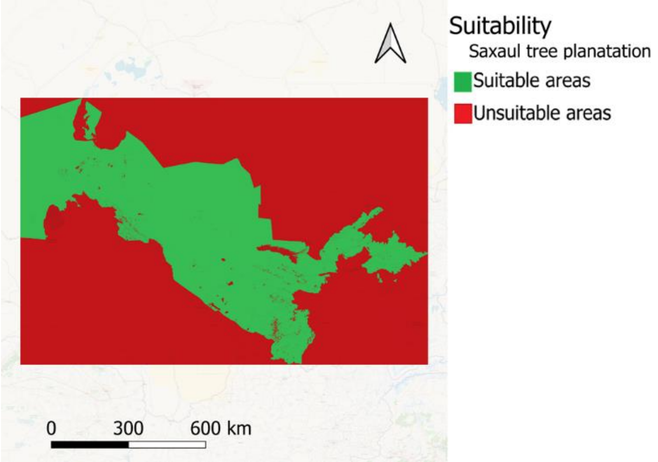
Appendix D: Clay percentage suitability for the three different SLMs

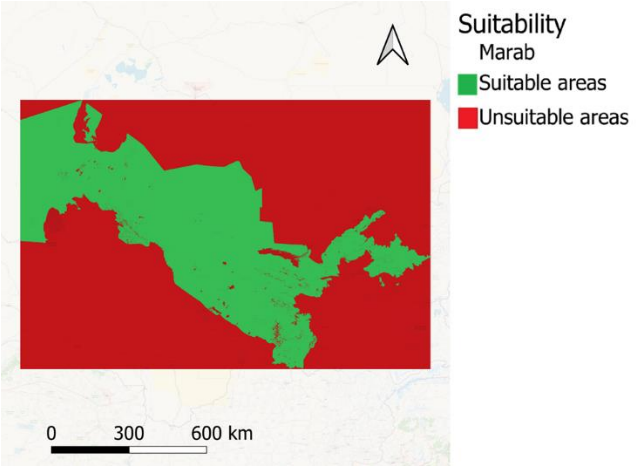


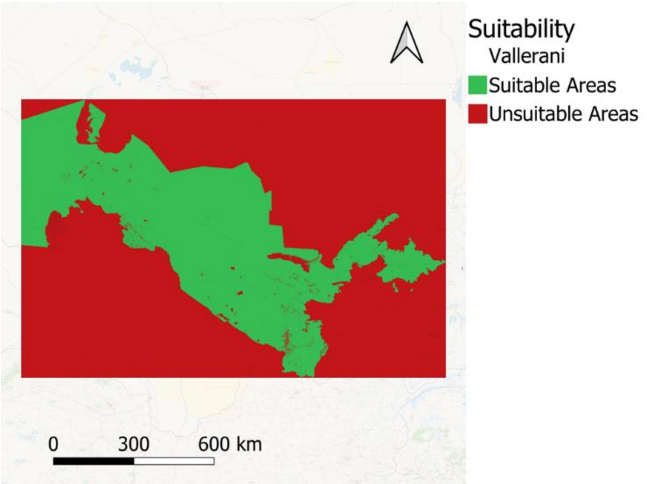




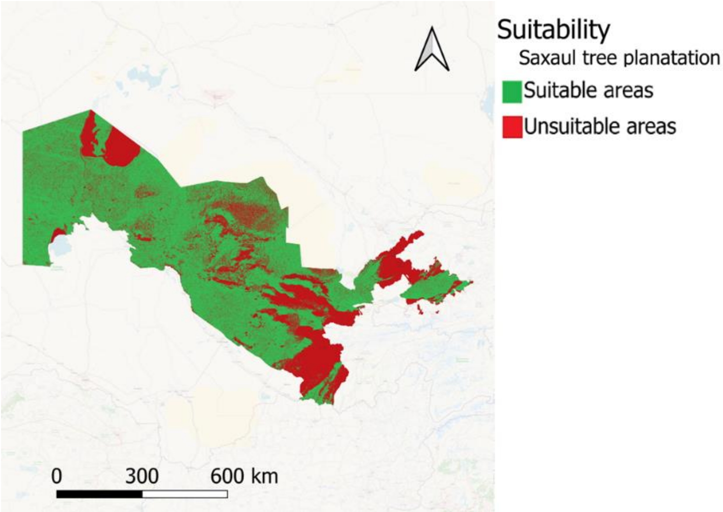
Appendix E: Elevation suitability for the three different SLMs

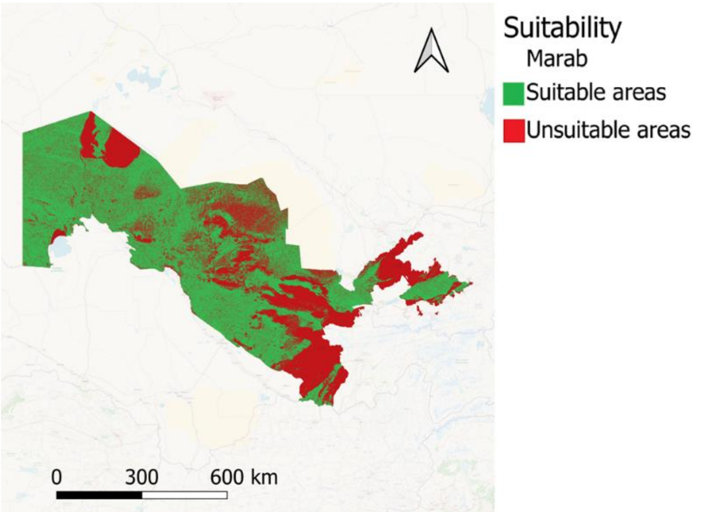


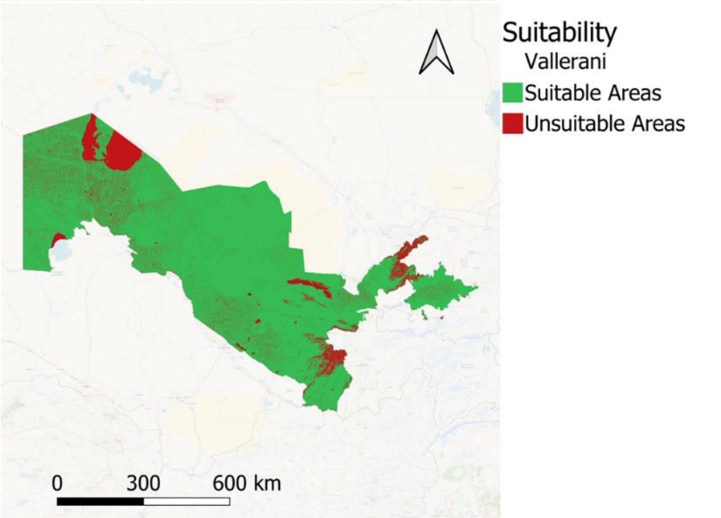




Appendix F: Slope suitability for the three different SLMs







Appendix G: Rainfall suitability for the three different SLMs