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Vegetation Mapping in Vashlovani National Park



**Sustainable Management of Pastures in Georgia to Demonstrate
Climate Change Mitigation and Adaptation Benefits and Dividends
for Local Communities (UNDP/EU).**

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The views expressed in this report are those of the author and do not necessarily represent those of the United Nations or UNDP.

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Executive summary

The study was conducted for the mapping of the vegetation of Vashlovani Protected Areas (VPA) within the framework of the project: **Sustainable Management of Pastures in Georgia to Demonstrate Climate Change Mitigation and Adaptation Benefits and Dividends for Local Communities** (UNDP/EU).

The work was carried out during 2 October to 10 December 2013 and involved a desktop study to classify the vegetation of VPA and its mapping using satellite imagery, GIS analysis and ground surveys.

All major plant communities found in Vashlovani protected areas were identified and a detailed map of vegetation cover was created for the first time. A total of 26 vegetation classes and subclasses were mapped on a 1:35,000 scale map.

1 Introduction

This report describes the study conducted for the creation of a detailed vegetation map for Vashlovani Protected Areas (VPA) which was carried out within the framework of the project: **Sustainable Management of Pastures in Georgia to Demonstrate Climate Change Mitigation and Adaptation Benefits and Dividends for Local Communities** (UNDP/EU).

The study was carried out during 2 October to 10 December 2013 and involved classifying and mapping the vegetation of VPA using satellite imagery, GIS analysis and ground surveys.

The study had a seasonal constraint since all necessary ground surveys had to be conducted in autumn months while spring is probably the best time to assess vegetation in Vashlovani. Nevertheless, based on existing knowledge and owing to a long-term experience of working in the study area, we were able to identify all major plant communities in Vashlovani and create a very detailed map of vegetation cover. It is, however, important to note that this is the first detailed vegetation map for Vashlovani and further fine-tuning may be required in the future.

2 Short description of the methodology.

Vashlovani features a very heterogeneous landscape in which the distribution of diverse vegetation is governed by a combination of natural and human factors that determine such variables as soil formation, moisture and precipitation as well as the level of solar radiation.

The environments such as present in Vashlovani are generally difficult to map with remotely-sensed data because:

- Many cover types do not exhibit unique spectral reflectance/absorbance characteristics that would distinguish one cover type from another.
- Topography often affects reflectance, differentiating sunlight and shadowed slopes.
- Even though vegetation distributions are generally related to an altitudinal gradient, recognized plant zones merge into each other on the margins, and the plants which are characteristic of one zone are often found in favorable sites in the neighboring zone above or below.

In this study, the RapidEye satellite data were combined with topographic, GPS and topo-climatic measures to determine the best set of classification variables for mapping vegetation communities along an altitudinal gradient from arid to montane plant zones.

Using RapidEye satellite data implied enhanced possibility to use a Red Edge band to map vegetation. The relevance of the Red Edge spectral region for vegetation characterization has been recognized for many years. Several studies have suggested that the transition between the red absorbance and the Near-Infrared (NIR) reflection is able to provide additional information about vegetation and its characteristics.

For satellite image interpretation and classification we used Fuzzy ARTMAP or Adaptive Resonance Theory (ART) algorithm based on neural network developed by *Grossberg* and *Carpenter*¹ and evolved from the biological theory of cognitive information processing. ART networks are designed, in particular, to resolve the stability-plasticity dilemma and exhibit a high degree of stability in order to preserve significant past learning, but remain adaptable enough to incorporate new information whenever it might appear². Fuzzy ART is a clustering algorithm that operates on vectors with fuzzy analog input patterns (real numbers between 0.0 and 1.0) and incorporates an incremental learning approach which allows it to learn continuously without forgetting previous learned states.

A total of 26 vegetation classes and subclasses were successfully mapped with a high level of accuracy on a 1:35,000 scale map.

3 An overview of the vegetation of Vashlovani protected areas

The vegetation of Vashlovani protected areas (Vashlovani National park and Vashlovani Nature Reserve) is characterized by remarkable diversity of plant communities some of which are represented in a number of variants and formations.

The most common plant communities include:

- Lowland and foothills deserts
- Phrygana-like vegetation
- Steppe
- Shibliak-like hemixeropilous scrub
- Arid light woodlands
- Foothills deciduous forest

There are also patches of flood plain forest, hygrophilous vegetation, humid scrub (conditional term), meadow-steppe, tragacanth and tomillar vegetation.

Of the above vegetation classes, lowland deserts, arid light woodlands, steppe and foothills forest are the zonal vegetation of the region (Kiziki district of Kakheti, East Georgia). The others are largely intrazonal and their occurrence is accounted for by local terrain and soil conditions.

The great variation in terrain and soil features results in a mosaic within the zonal vegetation. This is best expressed in the Kumuro and Bugha-Moedani areas as well as in the Lekistskali gorge in which areas desert, steppe and arid woodland communities are found in a complicated mosaic. The natural pattern of vegetation distribution has been greatly affected by human influence as a result of which secondary vegetation is also common throughout the study area.

Formerly cultivated lands feature vegetation that is drastically different from the surrounding undisturbed areas. A very distinct vegetation is also found at or near the livestock farms.

¹ Carpenter, G.A., Gjaja, M. N., Gopal, S., & Woodcock, C. E., 1997, ART neural networks for remote sensing: Vegetation classification from Landsat TM and terrain data. *IEEE Transactions on Geoscience and Remote Sensing*, 35(2), 308-325.

² Mannan, B. and Roy, J., 1998, Fuzzy ARTMAP supervised classification of multi-spectral remotely-sensed images. *International Journal of Remote Sensing*, 19, 767-774.

In total, 12 main vegetation classes were identified for the purpose of this project some of which are found in several distinct variants or subclasses (Table 1). As a result, as many as 26 plant formations have been mapped (see Annex 2 for map). Short descriptions of these plant formations are given in the next chapter.

Table 1: Main vegetation classes of Vashlovani protected areas

1. Steppe
1.1 Caucasian bluestem formations
1.1.1. Caucasian bluestem formations with artemisia
1.1.2. Caucasian bluestem formations with xerophilous herbs and ephemerals
1.1.3. Caucasian bluestem formations with mixed herbs
1.1.4. Caucasian bluestem formations with liquorice
1.1.5. Caucasian bluestem formations with <i>Stipa spp.</i> and mixed herbs
1.1.6. Caucasian bluestem formations with mixed grass and herbs.
1.1.7. Caucasian bluestem formations with Christ's thorn and herbs.
1.2 Needle grass formations
1.3 <i>Cleistogenes bulgarica</i> formations
2. Lowland desert vegetation*
2.1 Artemisia formations
2.1.1 Artemisia formations with ephemerals and ephemeroids
2.1.2 Artemisia formations with bluestem
2.1.3 Artemisia formations with <i>Salsola ericoides</i>
2.1.4 Artemisia formations with <i>Salsola dendroides</i>
2.2 <i>Salsola nodulosa</i> formations
2.2.1 <i>Salsola nodulosa</i> formations with <i>Artemisia lerchiana</i>
3. Meadow-steppe
3.1 Mixed grass and herbs
4. Shibliak-like hemixerophilous scrub
4. 1 Christ's thorn scrub
4.2 Polydominant scrub
5. Phrygana-like vegetation and foothills desert**
6. Foothill forest
7. Humid scrub
7.1 Salt cedar formations
8. Flood plain forest
9. Vegetation of disturbed land
9.1 Spontaneous vegetation
9.2 Johnson grass formations
10. Ruderal vegetation
11. Arid light woodland
11.1 Juniper forest
11.2 Pistachio forest
12. Hygrophilous vegetation
12.1 Reed beds

* This community includes two *Salsola* formations such as *Salsoleta dendroidis* and *Salsoleta ericoidis*, which have not been mapped due to extremely little distribution.

** Phrygana-like vegetation and foothills desert could not be reliably differentiated and have been combined for the mapping purposes.

Arid light woodlands (11,300 ha) steppe (8,200 ha) and Phrygana-like vegetation and foothills desert (6,200 ha) are the most widespread vegetation types in Vashlovani protected areas. The other classes cover much smaller areas – most of them less than 700 ha (Figure 1).

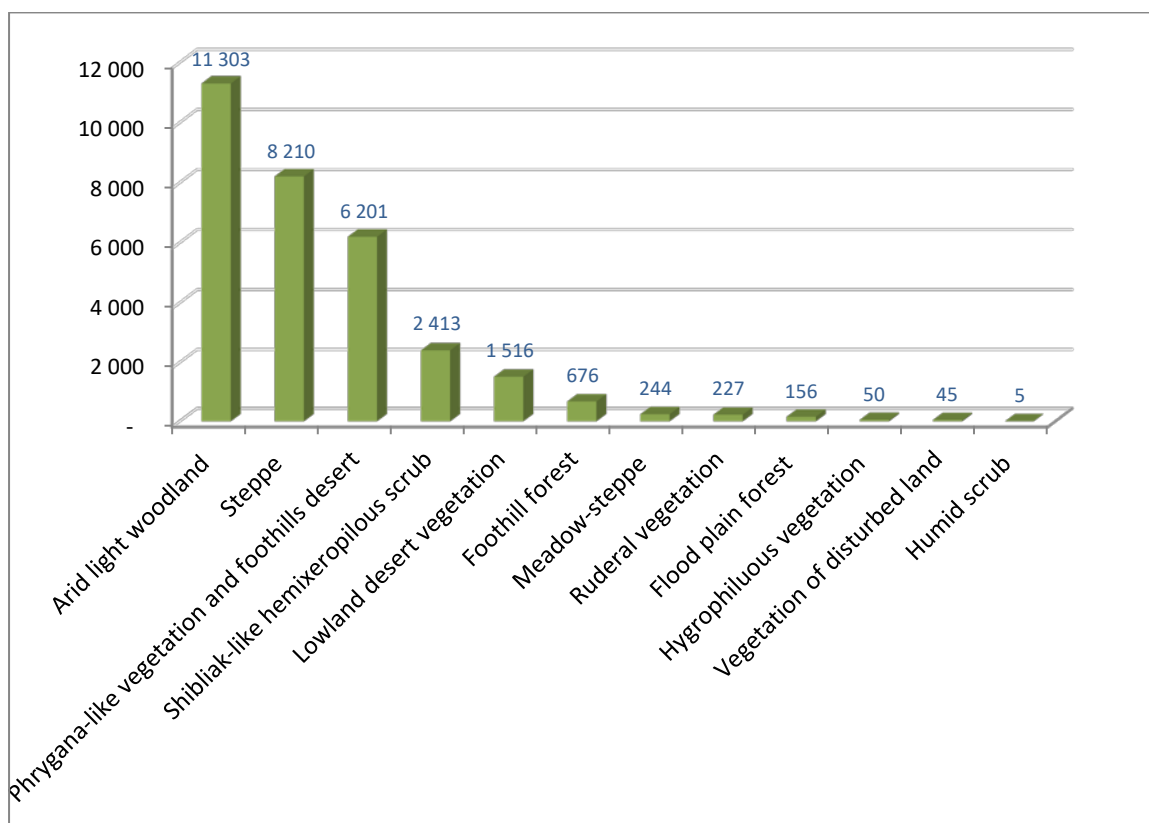


Figure 1: Distribution of main vegetation classes in Vashlovani protected areas.

4 Main vegetation classes and subclasses of Vashlovani Protected Areas

4.1 Steppe

As mentioned above steppe is one of the most widespread plant communities in Vashlovani covering a total of 8,210 ha and found throughout the study area in sections and patches of various sizes. It is represented by 3 distinct plant formations:

1. Caucasian bluestem formations
2. Needle grass formations
3. *Cleistogenes bulgarica* formations

Caucasian bluestem (*Bothriochloeta ischaemum*) formations are by far the most common type of steppe community in VPA. Up to 94 % of all steppe in Vashlovani is Caucasian bluestem steppe and it is in turn represented by numerous variants of which 7 main variants have been identified for

subsequent mapping. More xerophilous variants are found in southern and eastern sections of Vashlovani (Kumuro, the lower and middle sections of the Lekis-Tskali gorge, the flatlands of the Alazani gorge) and relatively mezophilous variants occur in the Shavi Mta (Black Mountain) area.

- Caucasian bluestem formations with artemisia (*Bothriochloetum artemisiosum*) are found in the Kumuro and Bugha-moedani areas, the Lekis-Tskalii gorge and the lower Alazani gorge. This is a transitional formation between Caucasian bluestem steppe and the artemisia desert and only covers about 155 ha (2%) of all bluestem steppe in Vashlovani.
- Caucasian bluestem formations with xerophilous herbs and ephemerals (*Bothriochloetum xeroherboso-ephemerosum*) is the most common steppe community that covers more than 5,000 ha - 67% of the bluestem steppe and nearly 63% of all steppe in Vashlovani. These formations occur on skeletal gray-brown soils of the southern slopes in Kumuro and Bugha-Moedani areas, the lower Lekis-Tskali gorge, the Black mountain area, etc. Associated plant species include: (xerophilous species): *Euphorbia seguieriana*, *Astragalus stevenianus*, *Teucrium polium*, *Scorzonera biebersteinii*, *Dianthus crinitus*, *Cleistogenes bulgarica*, *Astragalus bungeanus*, *Linum austriacum*, *Lagonychium fasrctum*, *Cousinia orientalis*, *Eryngium campestre*, *Medicago coerulea*, *Kochia prostrata*, etc; (ephemerals and ephemeroïds): *Lolium rigidum*, *Bromus japonicus*, *Medicago minima*, *Trachynia distachya*, *Linum corymbulosum*, *Phleum phleoides*, *Aegilops cylindrica*, *Trigonella spicata*, *Sideritis montana*, *Poa bulbosa* var. *vivipara*, *Allium pseudoflavum*, *Daucus carota*, *Xeranthemum squarrosum*, etc.
- Caucasian bluestem formations with mixed herbs (*Bothriochloetum varioherbosum*) are found in the Chighoeltkhevi gorge and on the hills north of the Eshmakis-Khevi. These formations are characterized by perennials such as: *Phlomis pungens*, *Glycyrrhiza glabra*, *Onobrychis radiata*, *O. kachetica*, *Eryngium campestre*, *Potentilla recta*, *Medicago coerulea*, *Salvia nemorosa*, *Galium verum*, *Allium atroviolaceum*, *Bilacunaria microcarpa*, *Plantago lanceolata*, etc.
- Caucasian bluestem formations with liquorice (*Bothriochloetum glycyrrhizosum*) are a rare variant only found in the form of very small patches on hills with relatively deep soil, in small depressions and flat spots. Nevertheless this variant is remarkably species rich particularly in forbs and grasses including: *Galium verum*, *Onobrychis radiata*, *O. kachetica*, *Stipa capillata*, *Eryngium campestre*, *Potentilla recta*, *Medicago coerulea*, *Stachys atherocalyx*, *Dianthus inamoenus*, *Koeleria cristata*, *Phleum phleoides*, *Polygalla transcaucasica*, etc.
- Caucasian bluestem formations with *Stipa* spp. and mixed herbs (*Bothriochloetum stiposo-varioherbosum*) is a relatively common variant that covers about 800 ha (11% of all bluestem steppe). It is mainly found on northern aspects in the Black mountain and the Eshmakiskhevi area, the Vashlovani depression and other sections of VPA. Depending on soil and terrain features, various *Stippa* species are present: *Stipa capillata*, *S. lessingiana* or *S. pulcherrima*. Among perennial forbs there are: *Crinitarria vilosa*, *Phlomis pungens*, *Polygalla transcaucasica*, *Glycyrrhiza glabra*, *Onobrychis kachetica*, *Potentilla adenophylla*, *Potentilla recta*, *Inula britanica*, *Serratula radiata*, *Galium verum*, *Stachys aterocalyx*, *Medicago coerulea*, *Seseli grandivittatum*, *Eryngium campestre*, *Allium pseudoflavum*, *Thymus tiflisiensis*, etc. Among grasses there are: *Cleistogenes bulgarica*, *Koeleria cristata*, *Phleum phleoides*, etc.

- Caucasian bluestem formations with mixed grass and herbs (*Bothriochloetum graminovarioherbosum*) are mainly found at the Black mountain. This is a rare variant of the bluestem steppe that covers only about 120 ha. Among perennials there are: *Phlomis pungens*, *Ph. tuberosa*, *Phleum phleoides*, *Dactylis glomerata*, *Galium verum*, *Inula germanica*, *Koeleria cristata*, *Stipa capillata*, *Stachys atherocalyx*, *Onobrychis radiata*, *Aster ibericus*, etc.
- Caucasian bluestem formations with Christ's thorn and herbs (*Bothriochloetum Paliuroso varioherbosum*) is a transitional formation between the bluestem steppe and Christ's thorn community in which Christ's thorn bushes are scattered on bluestem grassland. It is found mainly in the lower parts of the hills toward the Alazani river.

Needle grass formations (*Stipeta*; *S. capillata*, *S. lessingiana*) covers about 500 ha in all and in relatively larger patches is found mainly on and around the Black mountain. The variants with the dominance of *S. Capillata* are more common than those with *S. Lessingiana*. There are a number of variants of this steppe community each represented on very small areas. Characteristic plants include: *Glycyrrhiza glabra*, *Crinitaria villosa*, *Phlomis pungens*, *Bilacunaria microcarpa*, *Cleistogenes bulgarica*, *Festuca valesiaca*, *Phleum phleoides*, *Festuca valesiaca*, *Medicago coerulea*, *Galium verum*, *Potentilla recta*, *Teucrium nuchense*, *Eryngium campestre*, *Veronica multifida*, *Coronilla varia*, *Phlomis tuberosa*, *Crocus speciosus*, *Thlaspi perfoliatum*, *Arabidopsis thaliana*, *Holsteium imbellatum*, *Phleum paniculatum*, *Medicago minima*, *Onobrychis radiata*, *Aster ibericus*, etc.

***Cleistogenes bulgarica* formations** (*Cleistogenetum bulgaricae*) have a secondary origin and have developed to replace degraded communities of bluestem and artemisia. These formations are found in extremely small patches throughout Vashlovani. The only relatively large spot of this formation (43 ha) is found in the Mijnis Kure area.

4.2 Lowland desert communities

Lowland desert communities cover a total of up to 1,500 ha and are found in relatively flat terrain on soils with various level of salinity. There are 3 main formations as well as a number of transitional communities which develop in direct contact with steppe and arid light woodlands creating a mosaic of vegetation.

Artemisia formations (*Artemisieta lerchianae*) are found in relatively flat or slightly inclined areas with various levels of salinity. They are rather diverse and include a number of specific variants of which the following are most common:

- Artemisia formations with ephemerals and ephemerooids (*Artemisietum ephemerorum*) are found on low and medium salinity soils of the lower sections of the Alazani and Likis-Tskali gorges. Typical ephemerals and ephemerooids are: *Poa bulbosa* var. *vivipara*, *Medicago minima*, *Torularia contortuplicata*, *Allium rubellum*, *Adonis aestivalis*, *Alyssum desertorum*, *Astragalus asterias*, *Bombicilaena erecta*, *Bromus japonicus*, *Herniaria hirsuta*, *Lagoseris sancta*, *Sideritis montana*, *Veronica polita*, *Sisymbrium loeselii*, *Daucus carota*, *Erodium cicutarium*, *Filago pyramidata*, etc.

- Artemisia formations with bluestem (*Artemisietum-bothriochloosum*) mainly occur on low-salinity soils in the Kumuro, Bugha-Moedani areas and the Lekis-Tskali gorge, as well as in the lower section of the Alazani gorge. The relative importance of artemisia and bluestem varies from place to place; individual plants of *Salsola ericoides*, *Salsola dendroides*, *Kochia prostrata* may also mix. Typical ephemerals and ephemerooids are: *Poa bulbosa* var. *vivipara*, *Medicago minima*, *Torularia contortuplicata*, *Allium rubellum*, *Anagalis foemina*, *Bombicilaena erecta*, *Astragalus asterias*, *Erodium cicutarium*, *Bromus japonicus*, *Filago pyramidata*, *Lagoseris sancta*, *Lepidium vesicarium*, *Sideritis montana*, *Veronica polita*, *Valerianella rimosa*, *Sisymbrium loeselii*, *Daucus carota*, *Herniaria hirsuta*, *Phleum paniculatum*, etc.
- Artemisia formations with *Salsola ericoides* (*Artemisietum salsolosum ericoidis*) are the most common variant of artemisia community that are found in small patches of medium salinity soils in the Kumuro, Bugha-Moedani and the Lekis-Tskali areas. The relative importance of artemisia and *Salsola ericoides* varies greatly and some communities also feature bluestem, while others may have tiny patches of *Cleistogenes bulgarica*. Typical ephemerals and ephemerooids are same as above.
- Artemisia formations with *Salsola dendroides* (*Artemisietum salsolosum dendroidis*) is a very rare community that occurs on medium salinity soils mainly in the Kumuro and Likis-Tskali areas. *Salsola dendroides* is mostly scattered while in places may be more clumped. In some areas there are also *Salsola ericoides* and *Kochia prostrata*. Typical ephemerals and ephemerooids are same as above.

***Salsola dendroides* formations (*Salsoleta dendroidis*)³** are found in the form of a narrow strap in the Lekis-Tskali gorge. These formations are characterized by *Bothriochloa ischaemum*, *Salsola ericoides*, *Artemisia lerchiana* and are contaminated by *Artemisia annua*, *Silybum marianum*, *Centaurea solstitialis*, *Atriplex sp.*, *Filago sp.*, *Avena sp.*, *Peganum harmala*.

***Salsola ericoides* formations (*Salsoleta ericoidis*)³** are extremely rare in Vashlovani and are mainly found in the Kumuro and Bugha-Moedani areas in very small fragments. They are mixed with *Artemisia lerchiana*, *Bothriochloa ischaemum*, *Salsola dendroides* and contaminated by *Artemisia annua*, *Avena sp.*, *Daucus carota*, *Atriplex sp.*, *Silybum marianum*, species of the family *Brassicaceae*. The importance of *Cleistogenes bulgarica* is also notable.

***Salsola nodulosa* formations (*Salsoleta nodulosae*)** are very rare in Vashlovani as the main range of this community is outside the protected area in the lower Kumuro area and Eldari lowland. In Vashlovani these formations are represented by only one variant - *Salsola nodulosa* formations with *Artemisia lerchiana* (*Salsoletum-artemisiosum*) that is found on a highly saline spot in the Mijnis Kure area between the badlands and the flood plain.

4.3 Phrygana-like vegetation and foothills desert

Phrygana-like vegetation and foothills desert have been combined for mapping purposes.

³ These formations have an extremely small distribution and have not been mapped.

Phrygana-like vegetation develops on hills with clay and clay-sandy soils. The main formations are *Caraganeta grandiflorae* and *Reaumurieta alternifoliae*, while *Atraphaxietum spinosae* is less common. *Reaumurieta alternifoliae* is the most xerophilous of the three and by structure it is close to foothills desert. Characteristic species include: *Stachys fruticulosa*, *Artemisia lerchiana*, *Salsola nodulosa*, *Halothamnus glaucus*, *Agropyron pectinatum*, *Zygophyllum fabago*, *Caccinia rauwolfii*, *Capparis herbacea*, *Stipa caspia*, *Centaurea ovina*, *Matthiola odoratissima*, *Astrodaucus orientalis*, *Amberboa glauca*. Characteristic species of *Caraganeta grandiflorae* include: *Atraphaxis spinosa*, *Reaumuria alternifolia*, *Stachys fruticulosa*, *Artemisia lerchiana*, *Salsola nodulosa*, *Stipa lessingiana*, *Agropyron pectinatum*, *Zygophyllum fabago*, *Centaurea ovina*, *Astrodaucus orientalis*, *Amberboa glauca*, *Bupleurum wittmannii*.

Foothills desert are found in the form of badlands in which individual plants are very scattered, while some sections completely lack vegetation cover. In fragments that *do* have more or less developed vegetation cover, there are small communities of *Salsola nodulosa* and *Artemisia lerchiana*. Certain semi-bushes and xerophilous bushes are also typical. Ephemerals grow as individual plants. Characteristic species include: *Reaumuria alternifolia*, *Stachys fruticulosa*, *Atraphaxis spinosa*, *Halothamnus glaucus*, *Agropyron pectinatum*, *Zygophyllum fabago*, *Caccinia rauwolfii*, *Capparis herbacea*, *Stipa caspia*, *Scorzonera cana*, *Centaurea ovina*, *Matthiola odoratissima*, *Suaeda dendreoides*, *Astrodaucus orientalis*, *Amberboa glauca*, *Gamanthus pilosus*, *Bupleurum wittmannii*, *Lepidium vesicarium*, *Torularia eldarica*, *Eremopyron orientale*, *E. distans*. Rarely there are also *Atriplex cana* and *Camphorosma monspeliaca*.

4.4 Arid light forest

Arid light forest is one of the major vegetation types of Vashlovani protected areas. It is mostly found within the boundaries of the Vashlovani Nature Reserve. The main formations are juniper forest (*Junipereta*; *J. foetidissima*, *J. Polycarpus*) and pistachio forest (*Pistacieta muticae*). Transitional communities between the two are also quite common. Arid light forests in Vashlovani are rather diverse and exhibit several variants differing in structure and composition. For the purpose of this study only the above two main formations were differentiated and mapped.

Pistachio forest (*Pistacieta muticae*) is mainly found in low hills, flat spots and ravine terraces. Pistachio trees are sometimes mixed with junipers (*Juniperus foetidissima*, *J. polycarpus*). Between the pistachio trees and as undergrowth there are xerophilous bushes: *Paliurus spina-cristi*, *Cerasus microcarpa*, *Cetrasmus incana*, *Ephedra procera*, *Jasminum fruticans*, *Lonicera iberica*, *Rhamnus pallasii*, *Cotinus coggygria*, etc. The floor cover is steppe or semi-desert vegetation. Among the numerous variants of the pistachio forest community, the most important are: *Pistacietum bothriochloosum*, *Pistacietum stiposum*, *Pistacietum stiposo-bothriochloosum*, *Pistacietum artemisioso-bothriochloosum*, *Pistacietum artemisioso-salsolosum*, *Junipereto-Pistacietum mixtofruticosum*, *Junipereto-Pistacietum paliuroso bothriochloosum*.

Juniper forests (*Junipereta*; *J. foetidissima*, *J. Polycarpus*) mostly occur on northern aspects of medium and high inclination. The undergrowth is typically composed of the following bushes: *Jasminum fruticans*, *Paliurus spina-cristi*, *Cerasus microcarpa*, *Cerasus incana*, *Ephedra procera*, *Lonicera iberica*, *Rhamnus pallasii*, *Caragana grandiflora*, *Cotinus coggygria*. Rarely there are also *Carpinus orientalis* and *Ligustrum vulgare*. The floor cover is dominated by the non-woody species of

steppe, shibliak-like vegetation, xerophilous scrub and arid light forest. Sometimes there are species typical of desert and phrygana-like communities too. The main variants of the juniper forest include: *Pistacieto-Juniperetum jasminosopaliurosom*, *Pistacieto-Juniperetum caraganosom*, *Juniperetum caraganosom*, *Juniperetum jasminosomuscosom*, *Juniperetum mixtofruticosom*.

4.5 Shibliak-like hemixerophilous scrub

Shibliak-like hemixerophilous scrub is mainly found in the Chigoelt-Khevi and Eshamikis-Khevi gorges, and in the Black mountain area. Smaller fragments are also found within the ranges of steppe and arid light forest. There are both primary and secondary shibliak-like hemixerophilous scrub. The secondary communities have developed after the clearance of arid light and foothills forests.

Shibliak-like hemixerophilous scrub occurs on slopes of various aspects and inclination and is represented by a number of formations of which the following two are most important.

Christ's thorn formations (*Paliureta spina-christi*) are the most common type of the shibliak-like hemixerophilous scrub. Depending on aspect and elevation there are relatively xerophilous as well as more xeromezophilous variants of these formations. Specific variants include: *Paliuretum botriochloosom*, *Paliuretum gramino-mixtoherbosom* and *Paliuretum botriochlooso-stiposom*. The non-woody component is very species-rich and includes: *Bothriochloa ischaemum*, *Dactylis glomerata*, *Phleum phleoides*, *Stipa capillata*, *Phlomis pungens*, *Ph. tuberosa*, *Galium verum*, *Teucrium polium*, *T. nuchense*, *Inula germanica*, *I. britanica*, *Medicago coerulea*, *Festuca valesiaca*, *Salvia nemorosa*, *Seseli grandivittatum*, *Eryngium campestre*, *Bilacunaria microcarpa*, *Veronica multifida*, *Potentilla recta*, *Stachys atherocalys*, *Onobrychis radiata*, *O. kachetica*, *Asparagus verticillatus*, *Convolvulus cantabrica*, *Linum austriacum*.

Another important formation is **polydominant scrub (*mixtofruticeta*)**. These formations are mostly of secondary origin and are found in the form of fragments of various sizes within the larger ranges of steppe, Christ's thorn formations, arid light and foothills forests. The polydominant scrub communities which occur within the arid light woodlands, tend to be more xerophilous and are composed of the following bushes: *Paliurus spina-christi*, *Cotinus coggygria*, *Rhamnus pallasii*, *Jasminum fruticans*, *Cerasus incana*, *Cerasus microcarpa*, *Berberis iberica*, *Punica granatum*, *Lonicera iberica*, *Juniperus oxycedrus*, *Ephedra procera*. In the northern parts of the study area, polydominant scrub formations tend to become more xeromezophilous and are composed of: *Paliurus spina-christi*, *Cotinus coggygria*, *Lonicera iberica*, *Prunus spinosa*, *Mespilus germanica*, *Rosa canina*, *Ligustrum vulgare*, *Cotoneaster meyeri*, etc. Among tree species there are *Pyrus salicifolia*, *Celtis caucasica*, *Pistacia mutica*, etc.

4.6 Foothills deciduous forest

Deciduous forest has very limited distribution in Vashlovani protected areas. It is mostly found in the Black mountain and in fragments also in the ravines toward the Alazani (e.g. In Chaibulaki). Much of the deciduous forest in the Black mountain is ash (*Fraxinus excelsior*) stands. There are also some stands of oak (*Quercus iberica*). The undergrowth and forest floor vegetation are well-developed. The understory is dominated by *Carpinus orientalis*, *Euonymus verrucosa*, *Ligustrum vulgare*, *Swida*

australis, *Mespilus germanica*, *cogygria*, etc. The forest floor vegetation is composed of *Brachypodium sp.*, *Viola alba*, *V. odorata*, *Serratula quinquifolia*, *Smiranium perfoliatum*, *Scilla sibirica*, *Allium paradoxum*, *Aegonychon purpurea-coeruleum*, *Ficaria ledebourii*, *Crocus speciosus*, *Torilis japonica*, *Geranium lucidum*, etc.

There are also oriental hornbeam (*Carpinus orientalis*) stands that are mainly found on the northern, shadowed slopes of the ravines toward the Alazani river. In this forest, hornbeams grow as trees or as tall bushes while the community still retains a forest structure with understory and floor cover vegetation of herbs and mosses. The composition of the forest floor vegetation is similar to that of the ash and oak stands but is enriched with species typical of arid light forest and shibliak communities. Among tree species, there are: *Fraxinus excelsior*, *Acer ibericum*, *Acer campestre*, *Celtis caucasica*, *Juniperus foetidissima*. The understory is composed of *Ligustrum vulgare*, *Cotinus coggygria*, *Juniperus oxycedrus*, etc. The forest floor vegetation includes: *Brachypodium sp.*, *Silene italica*, *Viola alba*, etc.

4.7 Flood plain forest

Within VPA, flood plain forest is found in small fragments on the Alazani river terraces. The forest is mainly composed of oak (*Quercus pedunculiflora*) and black poplar (*Populus nigra*) stands.

4.8 Meadow-steppe vegetation

Meadow-steppe communities have a very limited distribution in VPA and are found in the Black mountain area as spots within the deciduous forest and scrub communities. They are represented by *Gramineto-mixtoherbeta* with such grasses as *Dactylis glomerata*, *Poa pratensis* and *Hordeum bulbosum*. Among forbs, there are species typical of steppe, dry grasslands and shibliak-like hemixerophilous scrub such as: *Bothriochloa ischaemum*, *Phleum phleoides*, *Stipa capillata*, *Phlomis pungens*, *Ph. tuberosa*, *Galium verum*, *Teucrium nuchense*, *Inula germanica*, *I. britannica*, *Medicago coerulea*, *Eryngium campestre*, *Veronica multifida*, *Potentilla recta*, *Stachys atherocalys*, *Salvia nemorosa*, *Bilacunaria microcarpa*, *Onobrychis radiata*, *O. kachetica*, *Stipa capillata*, *Filipendula vulgaris*, etc.

4.9 Humid scrub

Humid scrub is represented by salt cedar formations (*Tamariceta ramosissimae*) which have a very patchy distribution and are found along the rivers and dry ravines, and in depressed spots with moisture accumulation. Common reed (*Phragmites australis*) is an important component of salt cedar formations. There are also: *Limonium meyeri*, *Glycyrrhiza glabra*, *Elytrigia repens*.

4.10 Hygrophilous vegetation

Hygrophilous vegetation has a very fragmented distribution and is represented by common reed formations (*Phragmiteta australis*) of various sizes. Patches of this formation are found at the rivers and depressions with sufficient levels of moisture content.

4.11 Vegetation of disturbed (formerly cultivated) lands

Formerly cultivated lands cover only insignificant portion of the protected areas. Some sections already have vegetation that is similar to that of undisturbed surroundings. Elsewhere, the process of recovery of natural plant communities is underway.

Some sections of the formerly cultivated land feature **spontaneous vegetation** with underdeveloped structure. Spontaneous vegetation is found on north facing gentle slopes at the Alazani river. Different species prevail in different sections. Weeds and ruderal plants are rather common including: *Silybum marianum*, *Artemisia annua*, *Avena sp.*, *Echium biebersteinii*, *Cynodon dactylon*, *Daucus carota*, etc. Caucasian bluestem and more rarely liquorice formations are also found.

Formerly cultivated and irrigated Alazani terraces in Mijnis Kure have Johnson grass formations (*Sorghumeta halepensis*) that are incorporated into the larger artemisia community.

4.12 Ruderal vegetation

Ruderal vegetation is developed around or near livestock farms. Dominant plant species vary from farm to farm. Groupings of *Atriplex spp.* and *Chenopodium spp.* are most common. They are mixed with *Silybum marianum* and *Artemisia annua*. In some areas *Portulaca oleracea* is also very commonly spread.

ANNEX 1: List of used literature

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ANNEX 2: Map of the Vegetation of Vashlovani Protected Areas