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A land covers classification system for environment assessment in semi-arid regions of Iran

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Abstract

Land degradation is a major danger which restricting different areas of Iran. Systematic description of the environment for detection of environmental changes and the human-related causes and responses is essential in land cover change study. Use of land cover data allow detection of where certain changes occur, what type of change, as well as how the land is changing. Existing systems for classification of land cover is limited in the storage of the number of classes and is often internally inconsistent. Therefore, Food and Agriculture Organization of the United Nations (FAO), developed the land cover classification system (LCCS), a comprehensive parametric classification based upon systematic description of classes using a set of independent quantifiable diagnostic criteria. With this approach land cover change detection becomes possible at the level of conversion of a class, whereas modification within a certain class type becomes immediately identifiable by a difference in classifier, or through the use of additional classifiers as is shown in a series of examples illustrating the application of the approach to primarily vegetated areas. Our study showed this approach is match with exist information and dates for land cover mapping in Iran.

Keywords: Boolean formula; Classifier; Degradation; LCCS method; Environment

1. Introduction

According to the definition of the United Nations Convention to Combat Desertification (UNCCD), 'desertification' means land degradation in arid, semi-arid and dry sub humid areas resulting from various factors, including human activities and climatic variations. This land degradation was defined as the reduction or loss of biological or economic productivity and complexity in croplands, pastures, and woodlands (Tsunekawa, 2000). Identifying, delineating, and mapping land cover is important for resource management and planning programs. Land cover mapping is an essential tool used by natural resource managers as they struggle to protect habitat and plan against future loss and degradation.

The definition of land cover is fundamental, because in many existing classifications and legends it is confused with land use. According to the definition of the FAO, Land cover is the observed (bio) physical cover on the earth's surface (Di Gregorio and Jansen, 2005).

Land cover is principal factor, in both space and time, controlling the cycling and exchange of carbon, energy and water within, and between, the different earth systems. Thus, land covers classification are essential for a variety of diagnostic and predictive models that simulate the

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functioning of the earth systems and are useful for investigating regional and global change (Brown de Colstoun and Walthall, 2006). Efficient assessment of land cover and the ability to monitor change are fundamental to sustainable management of natural resources, environmental protection, food security and successful humanitarian programs. However, in the past, policy-makers and planners have not had access to reliable and comparable land cover data, not only for lower-income countries but also at the regional and global levels. The Land Cover Classification System (LCCS) has been developed by the Food and Agriculture Organization of the United Nations and the United Nations Environment Program (UNEP) to meet the need for improved access to reliable and standardized information on land cover and land cover change.

In this paper we introduce this approach and tested it in a semi arid area which has importance for managers of environment and natural resources.

2. Background

2.1. Existing classifications

Traditional classification systems dealing with land cover and/or land-use (Danserau, 1961; Fosberg, 1961; Trochain, 1961; Eiten, 1968; UNESCO, 1973; Mueller-Dombois and Ellenberg, 1974; Anderson et al., 1976; Kuechler and Zonneveld, 1988; ECE-UN, 1989; UNEP/FAO, 1994; CEC, 1995; Duhamel, 1995; Thompson, 1996) are limited in their capacity of storage of classes and often do not contain the whole variety of occurring land covers. Some describe (semi)natural vegetation in great detail while accommodating cultivated areas in a single class or vice versa. More important, they are based upon the approach of class names and class descriptions that do not consistently use a set of criteria to make class distinctions (Jansen and Di Gregorio, 1998). Furthermore, the criteria used are often not inherent characteristics but describe the environmental setting of the land cover and land-use, respectively.

2.2. Land covers classification system

2.2.1. Conceptual approach

The set of diagnostic criteria for the parametric classification approach followed in the land cover classification system (LCCS) developed by FAO is based upon examination of criteria commonly used in existing classifications that identify and describe land cover in an impartial, measurable and quantitative manner (FAO, 1997; Di Gregorio and Jansen, 1998 and 2000; Jansen and Di Gregorio, 1998a).

The developed approach to classification aims at a logical and functional hierarchical arrangement of the classifiers, thereby accommodating different levels of information, starting with broad-level classes which allow further systematic subdivision into more detailed subclasses. At each level the defined classes are mutually exclusive. Criteria used at one level of the classification are not to be repeated at other levels. The increase of detail in the description of a class is linked to the increase in the number of classifiers used. In other words, the more classifiers are added, the more detailed the class. The class boundary is then defined either by the different number of classifiers, or by the presence of one or more different types of classifiers. Emphasis is not given to the derived class name, the traditional method, but to the set of classifiers used to define this land cover class.

Many current classification systems are not suitable for mapping and subsequently monitoring purposes. In the developed parametric approach, the use of diagnostic criteria and their hierarchical arrangement to form a land cover class are a function of geographical accuracy. The arrangement of classifiers will assure at the highest levels of the classification, i.e. the most aggregated levels, a high degree of geographical accuracy.

Land cover should describe the whole observable bio-physical environment and is, thus, dealing with a heterogeneous set of classes. Evidently, a forest is defined with a set of classifiers different from those to describe snow-covered areas. Therefore, the definition of classes by classifiers is not using the same set of classifiers for description of every class because it would be impractical. In the new approach, the classifiers are tailored to each of the eight major land cover features identified (Fig. 1).

According to the general concept of an a priori classification, it is fundamental to the system that all combinations of the classifiers are accommodated in the system independent of scale and tools used to identify objects (e.g. human eye, statistics, aerial photographs or satellite remote sensing). By tailoring the set of classifiers to the land cover feature, appropriate combinations of sets of pre-defined classifiers can be made without the likelihood of impractical combinations of classifiers. Two distinct land cover features having the same set of classifiers may differ in the hierarchical arrangement of these classifiers in order to ensure a high geographical accuracy.

Having all pre-defined classes included in the system is the intrinsic rigidity of this type of classification. However, it is the most effective way to produce standardization of classification results between user-communities. The disadvantage is that in order to be able to describe any land cover occurring anywhere in the world in a consistent way, a huge number of pre-defined classes are needed and that users should describe a specific land cover feature in a similar way. This lead to the development of the application software that assists users in determination of classifiers in a stepwise selection procedure that aggregates classifiers to derive the land cover class. Two examples of this procedure are shown in Table 1.

Correlation with other existing classifications becomes a matter of translating the existing classes back into the classifiers of the system. Comparison of individual classes, as well as the used classifiers forming this class, becomes feasible. However, to be able to translate existing classes, documentation is needed on the criteria used. Individual class names are insufficient for any meaningful translation.

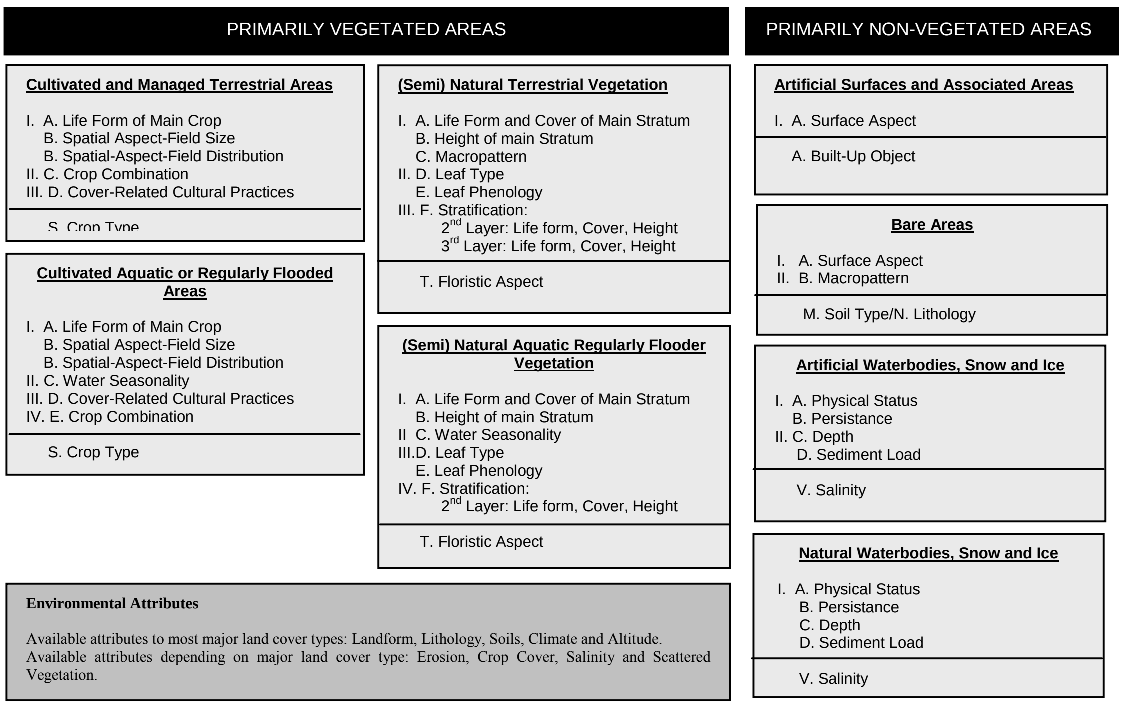

Fig. 1. The eight major land cover categories of LCCS-grouped under the primarily vegetated and primarily non-vegetated area distinction with their set of classifiers to form classes in hierarchical order (roman figures) followed by the specific technical attribute (e.g. crop type)

Table 1. Formation of LCCS classes by use of a set of classifier options with increasing level of detail of the class

Classifier	Boolean formula[a]	Standard Class Name
Natural and semi-natural terrestrial vegetation		
A. Life form and cover	A3A10	Closed forest
B. Height	A3A10B2	High closed forest
C. Spatial distribution	A3A10B2C1	Continuous closed forest
D. Leaf type	A3A10B2C1D1	Broadleaved closed forest
E. Leaf phenology	A3A10B2C1D1E2	Broadleaved deciduous forest
F. Stratificationb		
F. Second layer, life form and cover; G. height	A3A10B2C1D1E2F2F5F7G2	Multi-layered broadleaved deciduous forest
F. Third layer, life form and cover; G. height	A3A10B2C1D1E2F2F5F7G2F2F5F10G2	Multi-layered broadleaved deciduous forest with emergents
Cultivated and managed terrestrial areas		
A. Life form		
B. Spatial aspects:	A4	Graminoid crop(s)
Field size		
	A4B1	Large-to-medium sized field(s)
Field distribution		of graminoid crop(s)
	A4B1B5	Continuous large-to-medium
C. Crop combination		sized field(s) of graminoi crop(s)
	A4B1B5C1	Monoculture of large-to-medium
D. Cover-related cultural practices		sized field(s) of graminoi crop(s)
Water supply		fallow system
Cultivation time factor	A4B1B5C1D1	Rainfed graminoid crop(s) with
	A4B1B5C1D1D8	Rainfed graminoid crop(s)

[a] String of classifier codes selected; each code comprises a letter referring to the classifier and a figure referring to the classifier option selected.

[b] If an additional layer is present, the life form, cover and height need to be determined concurrently.

2.3. Application for environmental change detection

The advantages of the parametric approach are that change detection becomes possible at the level of conversion of a class and that modification within a certain class type becomes immediately identifiable by a difference in classifier or through the use of additional classifiers. Table 2 shows the conversion of a forest into a coffee (Coffea spp.) plantation (1) and a shrubland converted into a built-up area (2). Table 3 shows examples of modifications within the major land cover type but with a change in domain (e.g. the change of a single classifier (1) leads to a less rigid change in domain than several changed classifiers (2)), whereas Table 4 shows a land cover modification within the domain (e.g. the change of a single classifier or the use of additional classifiers). The LCCS will register modifications within the land cover type, that is from one domain to another (e.g. from “Forest” to “Woodland”, from “Shrubland” to “Sparse vegetation” or from “Tree crops” to “Herbaceous crops”) or within the domain (e.g. from “Multi-layered forest” to “Single-layered forest”, from “Small-sized fields of graminoid crops” to “Large-sized fields of graminoid crops”). The more classifiers used at the beginning of the monitoring process, the greater the detail of the defined class and the greater the possibility for detection of changes in any of the used parameters. The latter, however, is dependent on the method of measuring change.

The scale of the survey becomes an important issue concerning the number of used classifiers. Both scale and the means of surveying (e.g. interpretation of satellite imagery, field plot sampling or statistical methods) determine which criteria can be used, thus where the limits are placed.

Table 2. Detection of land cover modification within the major land cover type using the LCCS method showing defined classes with their set of classifiers and the classifier options selected[a]

Classifier	Classifier option	Classifier	Classifier option
Land cover modification within the major land cover type			
1. From "continuous closed forest" (left) to "continuous open forest (woodland)" (right)			
Life form of main layer	Trees	Life form of main Layer	Trees
Cover	Closed	Cover	Continuous
Height	Continuous	Height	>30m
Macropattern	>30m	Macropattern	Open
Leaf type	-	Leaf type	-
Leaf phenology	-	Leaf phenology	-
Second layer life form	-	Floristic aspect	-
Second layer cover	-	Second layer cover	-
Floristic aspect	-	Second layer height	-
Second layer height	-	Second layer life form	-
2. From "fragmented open high forest (woodland)" (left) to "sparse trees and sparse shrubs" (right)			
Life form of main layer	Trees	Life form of main layer	Trees
Cover	Fragmented	Cover	Sparse
Height	High	Height	>30m
Macropattern	Open	Macropattern	Parklike patches
Leaf type	-	Leaf type	–
Leaf phenology	-	Leaf phenology	–
Second layer life form	-	Second layer life form	Shrubs
Second layer cover	-	Second layer cover	–
Floristic aspect	-	Second layer height	5–0.3m
Second layer height		Floristic aspect	Sparse

[a] Notation "–" indicates that the classifier has not been used.

Table 3. Detection of land cover modification within the land cover domain using the LCCS method showing defined classes with their set of classifiers and the classifier options selected[a]

Classifier	Classifier option	Classifier	Classifier option
Land cover modification within the land cover domain from "small-sized field(s) of herbaceous crop(s)" (left) to "large-sized field(s) of irrigated herbaceous crop(s)" (right)			
Life form of main crop	Herbaceous	Life form of main crop	Herbaceous
Crop type	Small	Field size	Large
Field distribution	-	Field distribution	Continuous
Crop combination	-	Crop combination	-
Cover-related cultural	-	Cover-related cultural	-
Practices	-	Practices	-
Field size		Crop type	Irrigated

[a] Notation "–" indicates that the classifier has not been used.

3. Materials and methods

3.1. Study area

The study was carried out in Ghorkhoud region. It is a protected area that locate in Khorasan shomali province (950-3000 m a.s.l., 43000 ha, see fig 2). This area, comprise different landscape unit, including valley bottoms and ravines, plateaus with different degree of dissection and rocky hilly uplands. Mean annual precipitation is 360 mm and mean annual temperature in the region is 13 °C which the climate is cold semi-arid (Keshtkar, 2008).

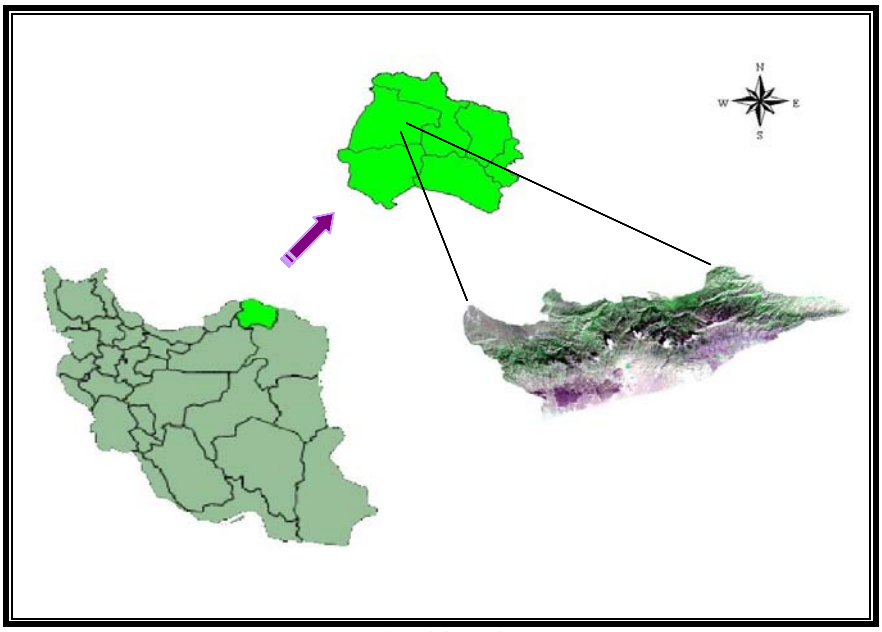

Fig 2. Location of the study area

3.2. Methods

From 5 May to 12 May 2007 it was sampled characteristic in 280 selected stands. We used topography maps with scales 1:50000 and vegetation cover map with scale 1:100000 for select sample points. Stands were defined as areas of 2×2 m, around the point located with the GPS (In woodlands stands were 10×10 m). For each stand it was recorded land cover type, list of plants, foliage area, height dominant species, topography position, slope, aspect, altitude and kind of erosion. In addition, we relied upon information from aerial photographs, images of satellite IRS-1D and pedological map. Finally, recorded dates entered in computer and used to LCCS software for analysis them.

4. Results

The first results showed that the study area consists of both man made and natural lands. Forest area include needle leaved evergreen. Nonforested areas, on the other hand, are composed of sparse shrub land, open shrub land, grassland and bare land. Remaining regions of the study area are covered with farm lands. The results analysis dates to be obtain of LCCS software are showing in Table 5 and 6.

5. Discussion and conclusions

Environmental change detection is a multidisciplinary subject and it is important that an integrated approach is taken with several partners involved to agree upon a widely accepted reference base for land cover classification. The parametric approach of the LCCS has proven to be pragmatic and serves a variety of users in their needs. The independent diagnostic criteria, the classifiers, standardize the description of classes in a systematic way. In turn, these criteria can be verified individually during the field sampling and they can be analytically used in change studies. The parametric land cover classification developed contributes to standardization of the systematic description of land cover classes and the diagnostic criteria provide a uniform basis for detection of land cover changes.

The proposed concept for future database development using standardized classifications as a reference base will facilitate comparison and correlation. The Africover-Eastern Africa Module was prepared land cover data sets on a uniform basis that is become available to users for a range of applications. We can do it in Iran and other countries in the Middle East, too. This approach was successfully tested in one case study but more work is required on definition of the diagnostic criteria in order to develop a reference base.

Table 5. The results analysis dates to be obtain of LCCS approach

Cultivated and Managed Terrestrial Area(s)

LCCS Code: 11252-12601-L11L5M2M620N1N1125O5O11P10Q6S7W4
LCCS Formula: A3B2XXC2D1D7-C3-L11L5M2M620N1N1125O5O11P10Q6S7W4
User's Label: ***Farm land***
LCCS Label: Shifting Cultivation of Small Sized Field(s) of Herbaceous Crop(s) (One Additional Crop).
Standard Descriptions:

Small-sized field(s) is covered by rainfed herbaceous crops. One or two additional inter planted crops can be specified growing on the field simultaneously or with an overlapping or sequential period. The crop covers the land during the cropping period of a fallow system.

LCCS User Defined Label:

Major Land class: Level Land, Plain, Slope Class: Flat To Almost Flat
Lithology: Sedimentary Rock, Age: Mesozoic – Jurassic
Soils: Bare Rock, Subsurface: Regosols
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1000-1500 m
Erosion: Water Erosion - Sheet
Crop Type: Fodder
Crop Cover: High > 60 %

Natural and Semi-Natural Primarily Terrestrial Vegetation

LCCS Code: 21273-12366-L22L8M2M620N2N4N1125O5O11P3Q7T3
LCCS Formula: A2A10B4XXE5F2F6F10G3-B13G10-L22L8M2M620N2N4N1125O5O11P3Q7T3
User's Label: ***Grassland***
LCCS Label: Short Herbaceous Vegetation with Dwarf Shrubs
Standard Descriptions:

The main layer consists of closed herbaceous vegetation. The crown cover is more than (70-60)%. The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The second layer consists of sparse shrubs.

LCCS User Defined Label:

Major Land class: Sloping Land, Medium-Gradient Hill, Slope Class: Hilly
Lithology: Sedimentary Rock, Age: Mesozoic - Jurassic
Soils: Soil Surface, Stony (5 - 40 %), Subsurface: Regosols
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1500 - 3000 m
Erosion: Water Erosion - Rill
Floristic Aspect: Dominant Species (Height, Cover or combination of both)

LCCS Code: 20134-13315-L31L9M2M620N2N5O5O11P3Q7T3
LCCS Formula: A3A11B2XXD2E1-B7E3-L31L9M2M620N2N5O5O11P3Q7T3
User's Label: ***Woodland***
LCCS Label: Mixed Woodland
Standard Descriptions:

The main layer consists of needleleaved evergreen woodland. The crown cover is between (70-60) and (20-10) %. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.

LCCS User Defined Label:

Major Land class: Steep Land, High-Gradient Mountain,
Slope Class: Steeply Dissected To Mountainous
Lithology: Sedimentary Rock, Age: Mesozoic - Jurassic
Soils: Soil Surface, Very Stony (40-80 %)
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1500 - 3000 m
Erosion: Water Erosion - Rill
Floristic Aspect: Dominant Species (Height, Cover or combination of both)

LCCS Code: 21112-12130-L22L8M2M620N2N4N1125O5O11P11Q7T3
LCCS Formula: A4A11B3XXD1E2F2F6F10G3-B10G9-L22L8M2M620N2N4N1125O5O11P11Q7T3
User's Label: ***Open-Shrubland***
LCCS Label: Broadleaved Deciduous Dwarf Shrubland with Medium High Shrub Emergents
Standard Descriptions:

The main layer consists of broadleaved deciduous shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5- 0.3m but may be further defined into a smaller range. The second layer consists of shrubs emergents.

LCCS User Defined Label:

Major Land class: Steep Land, High-Gradient Mountain, Slope Class: Steeply Dissected To Mountainous

Lithology: Sedimentary Rock, Age: Mesozoic - Jurassic
Soils: Soil Surface, Very Stony (40-80 %)
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1500 - 3000 m
Erosion: Water Erosion - Rill
Floristic Aspect: Dominant Species (Height, Cover or combination of both)

LCCS Code: 21412-6098-L12L5M2M620N2N5N1125O5O11P10Q6T3
LCCS Formula: A4A14B3XXD1E2F2F4F10G4-A15B10G12- L12L5M2M620N2N5N1125O5O11P10Q6T3
User's Label: ***Sparce-Shrubland***
LCCS Label: Broadleaved Deciduous Sparse ((20-10) - 4%) Dwarf Shrubs and Sparse Short Herbaceous
Standard Descriptions:
The main layer consists of broadleaved deciduous sparse shrubs. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The second layer consists of sparse herbaceous vegetation.
LCCS User Defined Label:
Major Land class: Level Land, Plateau, Slope Class: Flat To Almost Flat
Lithology: Sedimentary Rock, Age: Mesozoic - Jurassic
Soils: Soil Surface, Very Stony (40-80 %), Subsurface: Regosols
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1000-1500 m
Erosion: Water Erosion - Sheet
Floristic Aspect: Dominant Species (Height, Cover or combination of both)

Artificial Surfaces and Associated Area(s)

LCCS Code: 5003-15-L11L5O5O11P10
LCCS Formula: A4-A13A16-L11L5O5O11P10
User's Label: ***City area***
LCCS Label: Low Density Urban Area(s)
Standard Descriptions:
The land cover consists of non-linear built up areas which can be further specified into industrial area(s) or urban area(s). The density of the impermeable surface(s) can be specified into high, medium, low or scattered.
LCCS User Defined Label:
Major Land class: Level Land, Plain, Slope Class: Flat To Almost Flat
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1000-1500 m

Bare Area(s)

LCCS Code: 6005-7-L11L6M2M620N1125O5O11P10Q6U2
LCCS Formula: A5-A13-L11L6M2M620N1125O5O11P10Q6U2
User's Label: ***Bare land***
LCCS Label: Very Stony Bare Soil And/Or Other Unconsolidated Material(s)
Standard Descriptions:
The land cover consists of bare soil and/or other unconsolidated material(s). The surface can be stony (5 - 40%) or very stony (40 - 80%).
LCCS User Defined Label:
Major Land class: Level Land, Plain, Slope Class: Gently Undulating To Undulating
Lithology: Sedimentary Rock, Age: Mesozoic - Jurassic
Soils: Subsurface: Regosols
Climate: Temperate Continental - Dry Semi-arid
Altitude: 1000-1500 m
Erosion: Water Erosion - Sheet
Scattered Vegetation: Woody

Table 6. Land Cover Classification Legend

Artificial Surfaces and Associated Area(s)		**Bare Area(s)**	
A13	Urban Area(s)	A13	Very Stony (40 - 80%)
A16	Low Density	A5	Bare Soil And/Or Other Unconsolidated Material(s)
A4	Non-Linear (Feature)		
Natural and Semi-Natural Primarily Terrestrial Vegetation		**Cultivated and Managed Terrestrial Area(s)**	
A10	Closed > (70-60)% (Main Layer)	A3	Herbaceous Crops
A11	Open General (70-60) - (20-10)% (Main Layer)	B2	Small Sized Field(s)
A14	Sparse (20-10) - 1% (Main Layer)	C2	Intercropped (Second Crop)
A15	Sparse (20-10) - 4% (Main Layer)	C3	One Additional Crop
A2	Herbaceous Vegetation (Main Layer)	D1	Rainfed Cultivation
A3	Trees (Main Layer)	D7	Shifting Cultivation
A4	Shrubs (Main Layer)	S7	Fodder
B10	Dwarf - < 0.5m (Shrub Height Main Layer)	W4	High Crop Density (> 60%)
B13	Short		
B2	> 30 - 3m (Trees Height Main Layer)	**Environmental attributes**	
B3	5 - 0.3m (Shrubs Height Main Layer)		
B4	3 - 0.03m (Herbaceous Height Main Layer)	L11	Plain
B7	Low 7-3m (Trees Height Main Layer)	L12	Plateau
D1	Broadleaved	L22	Medium-Gradient Hill
D2	Needleleaved	L31	High-Gradient Mountain
E1	Evergreen	L5	Flat To Almost Flat Terrain
E2	Deciduous	L6	Gently Undulating To Undulating Terrain
E3	Mixed	L8	Hilly Terrain
E5	Mixed	L9	Steeply Dissected To Mountainous Terrain
F10	Sparse (20-10) - 5%	M620	Jurassic
F2	Second and/or Third Layer Present	N1	Bare Rock
F4	Herbaceous Vegetation (Second or Third Layer)	N1125	Regosols
F6	Shrubs (Second or Third Layer)	N2	Soil Surface
G10	Dwarf	N4	Stony (5 - 40%)
G12	Short 0.3-0.03m (Herbaceous Height Second Layer)	N5	Very Stony (40 - 80%)
G3	5 - 0.3m (Shrubs Height Second or Third Layer)	O11	Dry Semi-Arid
G4	3 - 0.03m (Herbaceous Height Second or Third Layer)	O5	Temperate Continental
G9	Medium High	P10	1000 - 1500 m
T3	Dominant Species (Height, Cover or Combination of Both)	P11	1500 - 2000 m
P3	1500 - 3000 m	Q6	Sheet Erosion
Q7	Rill Erosion	U2	Woody Vegetation

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