## What are AHCs?

AHCs or Agroecosystem Health Cards are handbooks that provide straightforward, practical explanations on how to assess the health of agricultural and stockbreeding ecosystems. In particular, AHCs allow the evaluation of the impact of our actions (e.g., agricultural practices) on agroecosystem health.

To this aim, AHCs specify what indicators of agroecosystem health one can measure, how to properly do so, what each indicator means, as well as the value intervals considered as "good", "average" and "bad" for a correct interpretation of each specific indicator.

## AHC-grassland agroecosystems

The here presented AHC has **been specifically designed for grasslands** and, in consequence, it must NOT be used for other types of ecosystems (in this respect, the specific set of indicators to be measured, as well as the reference values considered "good", "average" or "bad", should be modified accordingly).

This AHC has been developed by NEIKER - The Basque Institute of Agricultural Research and Development, in collaboration with the Zeanuri and Orozco Stockbreeders Associations, the Lorra Agro-Stockbreeding Cooperative, the Biscay County Council and the Basque Government, thanks to European Union funding (LIFE+ Programme - LIFE10NAT/ES/579 project).

The aim of this LIFE project is to assess the impact of agricultural practices usually carried out in grazing areas of the Gorbeia National Park (northern Spain) and its surroundings, in order to encourage the use of more sustainable practices from both a socio-economic (exploitation of livestock resources) and environmental (preserving biodiversity and combating climate change) point of view.

## Who can use the AHCs?

Anyone can use them. For this purpose, AHCs include a number of "basic" indicators that can be measured and interpreted without any special training or qualification. How? – simply by reading the AHC and using easy homemade instruments. Indeed, AHCs allow non-experts to properly diagnose the health of agroecosystems, though at a basic level (see page 25 in handbook).

In case you want to get a more comprehensive assessment, a number of "advanced" indicators, which require more sophisticated equipment and prior training and qualification, have to be measured. NEIKER (contact: imijangos@neiker.net - ialbizu@neiker.net) has the infrastructure and expertise to determine and interpret these "advanced" indicators, in order to achieve a more comprehensive assessment of agroecosystem health (see page 26 in handbook).

## How can one determine the health of an agroecosystem?

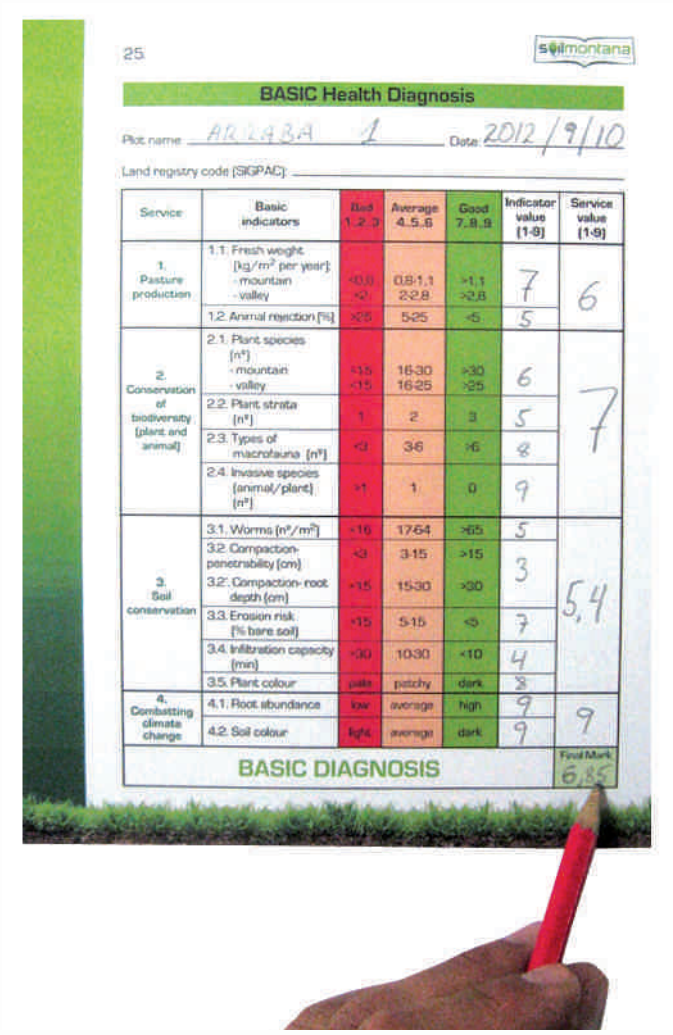
• Data collection and health diagnosis:

Every time we measure an indicator, we have to compare the obtained value with the reference values considered "bad", "average" or "good" (see tables for data collection in pages 25 and 26), so that we can assign it a value from 1 to 9 (indicator value, in the last column but one).

Both "basic" and "advanced" indicators are grouped into a variety of ecosystem services provided by healthy agroecosystems. If we calculate the mean value of all indicators included in a particular ecosystem service, we will know to what extent -from 1 to 9- our agroecosystem can provide that specific service (service value, in the last column).

Finally, a **value of overall health** for our agroecosystem can be obtained by calculating the mean value -from 1 to 9- of all measured ecosystem services (Final Mark*, last box).

See the example below (page 3).



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**BASIC Health Diagnosis**

Plot name: ARIABA 1 Date: 2012/9/10

Land registry code (SIGPAC):

| Service | Basic indicators | Bad 1.2.3 | Average 4.5.6 | Good 7.8.9 | Indicator value (1-9) | Service value (1-9) |
|---|---|---|---|---|---|---|
| 1. Pasture production | 1.1. Fresh weight [kg/m² per year]: - mountain - valley | <0.6 <2 | 0.8-1.1 2-2.8 | >1.1 >2.8 | 7 | 6 |
| | 1.2. Animal rejection [%] | >25 | 5-25 | <5 | 5 | |
| 2. Conservation of biodiversity (plant and animal) | 2.1. Plant species [n°] - mountain - valley | <15 <15 | 16-30 16-25 | >30 >25 | 6 | 7 |
| | 2.2. Plant strata [n°] | 1 | 2 | 3 | 5 | |
| | 2.3. Types of macrofauna [n°] | <3 | 3-6 | >6 | 8 | |
| | 2.4. Invasive species (animal/plant) [n°] | >1 | 1 | 0 | 9 | |
| 3. Soil conservation | 3.1. Worms [n°/m²] | <16 | 17-64 | >65 | 5 | 5,4 |
| | 3.2. Compaction-penetrability [cm] | <3 | 3-15 | >15 | 3 | |
| | 3.2'. Compaction- root depth [cm] | <15 | 15-30 | >30 | | |
| | 3.3. Erosion risk [% bare soil] | >15 | 5-15 | <5 | 7 | |
| | 3.4. Infiltration capacity [min] | >30 | 10-30 | <10 | 4 | |
| | 3.5. Plant colour | pale | patchy | dark | 8 | |
| 4. Combatting climate change | 4.1. Root abundance | low | average | high | 9 | 9 |
| | 4.2. Soil colour | light | average | dark | 9 | |
| BASIC DIAGNOSIS | | | | | | Final Mark 6,85 |

*Note 1: A healthy agroecosystem is expected to be able to provide all ecosystem services listed in the table. Therefore, a value <5 in the assessment of any ecosystem service entails a "bad" overall health diagnosis, even if the overall average value is greater than 5.

*Note 2: In order to adapt the AHCs to the possibilities of each user, when all indicators listed in the table cannot be measured, the same calculations for the specific indicators and ecosystem services actually measured will be carried out. However, one must take into account that this can possibly affect the reliability and comprehensive nature of the diagnosis.

## How do I meaure each indicator?

You should take the following comments into account, before reading the instructions on how to measure each indicator:

- When to measure: Preferably in the spring (autumn as the second option), as this is when the biological indicators we are measuring are most active. Try to take your measurements 2 to 5 days after significant rainfall to avoid the soil being too wet or too dry. Also avoid especially hot or cold days (or times of day), as this also affects the activity of living organisms.

- How to measure: Follow the instructions in the manual and make sure you always do so in the same way (same person, technique, etc.), as the reliability of the diagnosis will depend on this. Any visibly different areas (vegetation, slope, humidity, etc) in the plot you are studying should be assessed separately.

Cheer up! Don't be disheartened if the absolute values that you find on your plot at first are poor (they will largely depend of local natural edaphoclimatic conditions). What is really important is that you observe how they change from year to year as a result of your good/bad practices. In order to do so, conditions during measurement (environmental and methodological) should always be the same, whenever possible.

# BASIC HEALTH DIAGNOSIS-INDICATORS

## 1. PASTURE PRODUCTION

### 1.1. Production-Fresh weight (kg/$m^2$ per year)

Cut the vegetation in an area 0.5 metres square (not being used for grazing) and weigh it immediately or keep it in a plastic bag until you can do so, to avoid the loss of humidity. Repeat the operation in four different areas within the area you want to assess and add up the weights (in kilos).

You should carry out this procedure several times throughout the year (at least once every season, ideally once a month to simulate better the grazing effect).

Compare the result of your measurement (kg/$m^2$ per year) with the reference values in the basic indicator table (at the end of the manual) to allocate it a value from 1 to 9*. Write down the value of the indicator in the table.

*Notice that the reference values are different for valley (more productive) and mountain pastures.

### 1.2. Production-Animal rejection (%)

Visually estimate the percentage of the pasture surface covered by stains that the livestock rejects and which is therefore no use as forage. Compare your measurement (as a %) with the reference values in the basic indicator table.

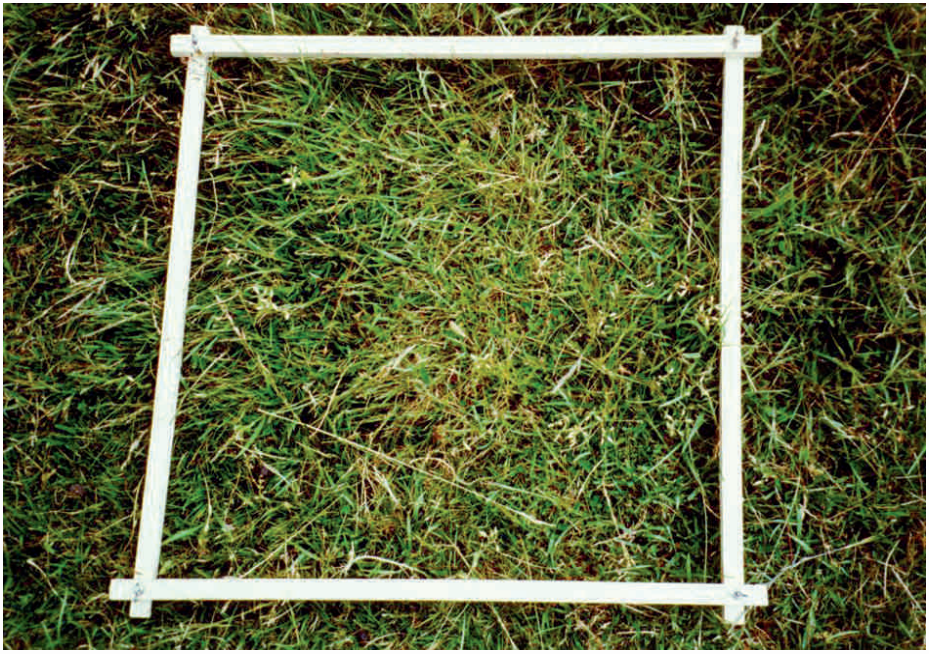
## 2. CONSERVATION OF BIODIVERSITY

### 2.1. Biodiversity-Plant species (nº)

Take an area 0.5 metres square within the study area and count the number of different plant species within the square (you don't have to identify them). Throw the frame again and add up the number of new species you find. Repeat the operation until no new species appear (5-10 throws are normally needed) and write down the total numer of different species in your study areao.

Compare the result of your measurement (nº) with the reference values in the basic indicator table. Remember that the reference values for valley bottom and mountain pastures are different.

High plant diversity does not just a per se value, but also indicates a pasture with high nutritional value able to adapt to change (e.g. drought.).



2.2. Biodiversity-Plant strata (nº)

Visually identify whether 3, 2 or 1 plant strata are present in your study (herbaceous, shrub and woodland). Compare the result (nº) with the reference values in the basic indicator table: 3 strata equal an indicator value of 8, 2 strata give 5 points and 1 strata gives 2 points.

The shrubs and/or trees that accompany the herbaceous strata provide shelter for the livestock and generate new ecological niches both above and below ground (root system) that can be inhabited by many organisms.

2.3. Biodiversity-Types of macrofauna (nº)

Use a flat shovel to extract a block of soil 30 cm deep and 25 cm per side. Try to do so in less than a minute to avoid organisms escaping to lower strata. Examine the surface first, then crumble it by hand and, using the following pictures, count the different kinds of macrofauna that are present (NOT the individuals). Repeat the operation 3 more times, calculate the average number of kinds of macrofauna found and compare the result (nº) with the reference values in the basic indicator table.

Macrofauna are the upper link in the trophic chain of the soil and start the decomposition process of organic materials, breaking up the larger remains, thus making them available to the meso and microfauna.

# MACROFAUNA
## (TYPES)

| | | | |
|---|---|---|---|
| 1. Worms **(Oligochaeta)**<br>2. Cockroaches **(Dictyoptera)**<br>3. Woodlice **(Isópoda)** |  1 |  2 |  3 |
| 4. Millipedes **(Diplopoda)**<br>5. Centipedes **(Chilopoda)**<br>6. Earwigs **(Dermaptera)** |  4 |  5 |  6 |
| 7. Ants **(Hymenoptera)**<br>8. Termites **(Isoptera)**<br>9. Grasshoppers **(Orthoptera)** |  7 |  8 |  9 |
| 10. Beetles **(Coleoptera)**<br>11. True bugs **(Heteroptera)**<br>12. Spiders **(Arachnida)** |  10 |  11 |  12 |
| 13. Snails **(Gasteropoda)**<br>14. Cicadas **(Homoptera)**<br>15. Others **(larvae, etc.)** |  13 |  14 |  15 |

## 2.4. Biodiversity-Invasive species (nº)

Visually check whether there is any plant or animal species that is regarded as invasive in your study and compare the result (nº) with the reference values in the basic indicator table.

Below, we have pictures of some of the invasive species that are most dangerous because of their colonisation capacity and the fact that they are increasingly spreading throughout the Basque Autonomous Region (IHOBE, 2009). You can download free IHOBE catalogues of invasive flora and fauna from the project website: www.soilmontana.net

Cortaderia selloana

Buddleja davidii

Fallopia japonica

Crocosmia x crocosmiflora

Robinia pseudoacacia

Cyperus eragrostis

These and other species threaten autocthonous vegetation as a result of their great colonisation capacity.

## 3. SOIL CONSERVATION

### 3.1. Soil-Worms (nº/m²)

This indicator is measured at the same time as diversity of macrofauna (see indicator 2.3). Count the number of worms (individuals) present in each of the 4 soil samples extracted (25x25x30 cm), add them up and multiply the total by 4 to find the number of worms per square metre. Compare this figure (nº /m²) with the reference values in the basic indicator table.

Worms prefer neutral soils rich in organic material, where they favour the penetration of roots, water, nutrients and air through their tunnel networks, thus reducing adverse effects of soil compaction.

### 3.2. Soil-Compaction

Use two measurements to assess this indicator:

Measurement 1 - Penetrability (cm): Take a corrugated rod 1 metre long and 8 mm in diameter (commonly used in building) and push it in the soil as far as you can with a modest effort. If you hit a stone, try again nearby. Repeat the operation 3 more times in your study area and compare the average depth reached (in cm) with the reference values in the basic indicator table.

Measurement 2 - Root depth (cm): Observe the soil profile of each of the 4 x 30 cm deep holes remaining after extracting the soil blocks (measurements 2.3. and 3.1.), observe the maximum depth reached by a significant number of roots. Compare this value (in cm) with the reference values in the basic indicator table.

The two measurements give an idea of the difficulty of root to go deep into the soil, depending on the degree of soil compaction.

### 3.3. Soil-Erosion risk (% bare soil)

Visually estimate the percentage of the soil surface that is bare (no vegetation) in your study area and compare the result (as a %) with the reference values in the basic indicator table. Bare soil is exposed to erosion by wind and water, especially on steep slopes.

### 3.4. Soil-Infiltration capacity (min)

Take a galvanised steel tube with an internal diameter of 15 cm (commonly used in building) and cut off a 10 cm long section, leaving one of the ends slanting to make it easier to insert in the soil. Use a hammer and a block of wood to insert it 2 cm into the soil, avoiding such discontinuities as gaps, stones, sticks. Gently pour 0.5 litres of water into the tube (if you use a 10 cm diameter tube, pour 230 millilitres). Wait until the water disappears and gently pour in another 0.5 litres of water, this time writing down the time it takes for the water to disappear. Repeat the operation at 3 more points in your area of study and compare the average inflitration time (in minutes) with the reference values in the basic indicator table.

Said volume of water corresponds to the amount of water that falls per hour inside the tube with heavy-very heavy rainfall. If it takes too long to infiltrate, it will run off the surface, acceleratting soil erosion.

### 3.5. Soil-Plant colour (category)

Visually check whether the vegetation in your study area is generally pale green, patchy (a mosaic of different shades) or dark green (bottle green) and compare it with the reference values in the basic indicator table.

If not due to drought, a pale yellow pasture colour may indicate a lack of certain nutrients in the soil (frequently nitrogen).

## 4. COMBATTING CLIMATE CHANGE

### 4.1. Climate change-Abundance of roots (category)

This indicator is measured at the same time as the macrofauna (indicator 2.3), worms (3.1) and root depth (3.2.). Visuallly estimate if the abundance of roots in the 4 soil blocks extracted (25x25x30 cm) could largely be regarded as low, medium or high and compare it with the reference values in the basic indicator table.

Plants exudate through roots C compounds synthesized by leaves. Besides, when plants die and decompose, the roots themselves provide a significant amount of C for the soil.

### 4.2. Climate change-Soil colour (category)

This indicator is measured at the same time as the previous ones (2.3, 3.1, 3.2 and 4.1). Visually estimate whether the soil is generally light, medium or dark and compare it with the reference values in the basic indicator table.

Soils rich in organic material are normally dark, indicating that they contain a large amount of C “sequestered” from the atmosphere.

# ADVANCED HEALTH DIAGNOSIS-INDICATORS

## 1. PASTURE PRODUCTION

1.1. Production-Dry weight (t/ha per year)

This is a similar measurement to the "basic" 1.1 indicator (fresh weight), since it shows us the production capacity (vigour) of our agroecosystem. However, this "advanced" production measurement (dry weight) has the advantage of overcoming natural fluctuations in the water content of the grass that could make us estimate its productivity wrongly. To do this, a representative sample of cut material is dried while avoiding its deterioration (normally at 70º centigrade under forced ventilation for 48 hours) and then weighed. This gives us the dry material percentage (DM) and we can compare our value for t DM/ha per year with the reference values in the advanced indicator table.

## 2. CONSERVATION OF BIODIVERSITY

### 2.1. Plant biodiversity-Shannon index (H')

We can use the specific richness and plant cover data obtained by basic measurement 2.1 to calculate the Shannon plant diversity index (H'), using the formula $H' = -\sum pi \log(pi)$. With pi being the relative abundance of each botanical species. Compare the result of your measurement (H') with the reference values in the advanced indicators table. Note that these reference values are different for valley bottom and mountain pastures.

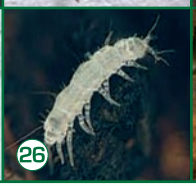
This index not only takes into account the number of plant species but also the proportionality of the relative abundance.

### 2.2. Biodiversity-Mesofauna (index)

Take a cylindrical soil sample 10 cm in diameter and 5 cm deep. To extract the mesofauna, place a 2 mm metal mesh (e.g. a strainer) over a funnel. Place the soil cylinder in the strainer beneath a 50 W bulb 20 cm away. Collect the organisms by placing a small jar containing alcohol beneath the funnel and use a magnifying glass and the following pictures to count the different types of mesofauna present (NOT the individuals), assigning them the value that appears in red next to the name of each group. Add up these values to obtain the biodiversity index. Repeat the operation at 3 more points in your study area and compare the average (index) with the reference values. You can find more information about the Berlese-Tullgren extraction method on the project website: www.soilmontana.net

The mesofauna make up the trophic link below the macrofauna and carry on with the decomposition process initiated by the latter.

# MESOFAUNA (TYPES)

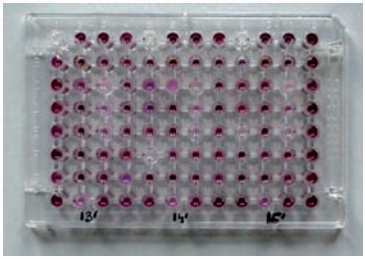
| | | | | |
|---|---|---|---|---|
| 1. Protura 20<br>2. Diplura 20<br>3. Collembola 10<br>4. Microcoryphia 10 |  |  |  |  |
| 5. Zygentomata 10<br>6. Dermaptera 1<br>7. Orthoptera 10<br>8. Embioptera 10 |  |  |  |  |
| 9. Blattaria 5<br>10. Psocoptera 1<br>11. Hemiptera 5<br>12. Thysanoptera 1 |  |  |  |  |
| 13. Coleoptera 10<br>14. Hymenoptera 3<br>15. Diptera (L) 10<br>16. Holometabolous (L) 10 |  |  |  |  |
| 17. Holometabolous 1<br>18. Acari 20<br>19. Araneae 3<br>20. Opiliones 10 |  |  |  |  |
| 21. Palpigradi 20<br>22. Pseudoscorpion 20<br>23. Isopoda 10<br>24. Chiliopoda 15 |  |  |  |  |
| 25. Diplopoda 15<br>26. Pauropoda 20<br>27. Symphyla 20 |  |  |  | |

2.3. Biodiversity-Functional in fungi (H')

- Sampling: within the study area take 4 random soil samples, each consisting of 10 samples of surface soil extracted with a probe 10 cm long and 2.5 cm in diameter.

- Processing: Homogenise the samples, sieve them (mesh=2mm) and store at 4ºC until their analysis that should be done within 2 months, to avoid changes to the sample.

- Laboratory analysis: At 490nm, measure the capacity of the soil fungi to degrade the 95 substrates on the Biolog$^{R}$ FF microplates and calculate their Shannon functional diversity index, using the procedure described by Shugeng at al. (2009). For more information, check our website: www.soilmontana.net



2.4. Biodiversity-Functional in bacteria (H')

- Sampling and processing: See above the advanced indicator 2.3.

- Laboratory analysis: At 595nm, measure the capacity of the soil fungi to degrade the 31 substrates on the Biolog$^{R}$ ECO microplates and calculate their Shannon functional diversity index, using the procedure described by Mijangos et al. (2009). For more information, check our website: www.soilmontana.net

2.5. Biodiversity-Genetic in fungi (H')

- Sampling : See advanced indicator 2.3.

- Procesing: Homogenise the samples, sieve them (mesh=2mm) and store at 4ºC until their analysis that should be done within 2 months, to avoid changes to the sample. Prolonged storage requires the samples to be frozen (< -20ºC).

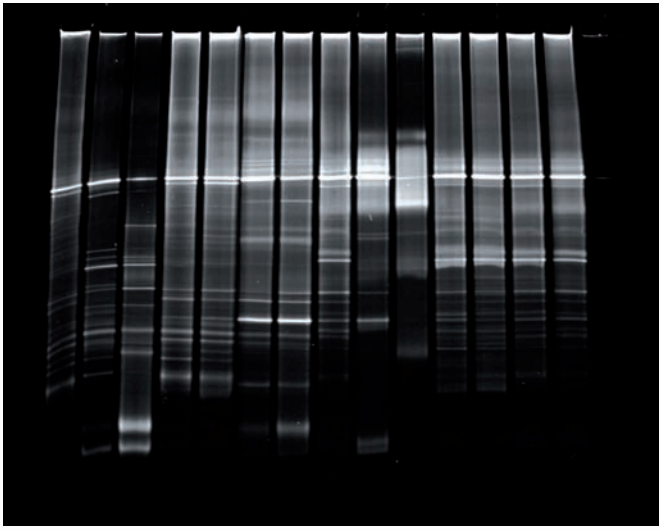
- Laboratory analysis: The DNA of the fungi is extracted (MoBio$^{R}$ kit), amplified (PCR), separated (DGGE) and its Shannon functional diversity index (H') is calculated, using the procedure described by Epelde et al. (2012). For more information, check our website: www.soilmontana.net

2.6. Biodiversity-Genetic in bacteria (H')

- Sampling: See advanced indicator 2.3.

- Processing: See advanced indicator 2.5. above.

- Laboratory analysis: The DNA of the fungi is extracted (MoBio$^R$ kit), amplified (PCR), separated (DGGE) and its Shannon functional diversity index (H') is calculated, using the procedure described by Mijangos et al. (2009). For more information, check our website: www.soilmontana.net



2.7. Biodiversity-Total Genetic (composition and abundance of OTUs)

- Sampling: See advanced indicator 2.3.

- Processing: See advanced indicator 2.5.

- Laboratory analysis: The total DNA of the soil is extracted and sequenced by high-performance processing techniques. The composition and abundance of the OTUs is calculated using the procedure described by Zinger et al. (2011). For more information, check our website: www.soilmontana.net

The great diversity of microorganisms that live in the soil do not just have a "per se" value but also are responsible for multiple soil functions (produce pasture, sequester $CO_2$, etc) and adapt to changes.

## 3. SOIL CONSERVATION

3.1. Soil-Microbial activity: Basal respiration (mg C-$CO_2$/kg per hour)

- Sampling and processing: See advanced indicator 2.3.

-Laboratory analysis: The $CO_2$ emission rate of the soil is measured for the first 3 days of incubation in hermetic jars at 30ºC, in the presence of an NaOH solution without adding external nutrients, as described in ISO 16072 method (2002). For more information, check our website: www.soilmontana.net

High basal respiration indicates that the soil is active and thus working. However, it also means more $CO_2$ is being emitted.

3.2. Soil-Microbial abundance:
Substrate-induced respiration (mg C-$CO_2$/kg per hour)

- Sampling and processing: See advanced indicator 2.3.

- Laboratory analysis: Taking the soil that has been incubated at 30ºC for 3 days in the previous measurement, measure its $CO_2$ emission rate for the first 6 hours of incubation (also at 30ºC and in the presence of an NaOH solution) immediately after the addition of a nutritient solution, consisting of a mixture of glucose, $KH_2PO_4$ and $(NH4)_2SO_4$, as described in ISO 17155 method (2002). For more information, check our website: www.soilmontana.net

A healthy soil rich in nutrients can contain a large number of microorganisms (~ 1 ton per hectare in temperate pastures) that carry out 80-90% of the biological activity of the soil (decontaminating and recycling nutrients, sequester $CO_2$, etc.).

3.3. Soil-Microbial efficiency: Metabolic quotient ($qCO_2$)

This is calculated by dividing the basal respiration (nº 3.1) and substrate-induced (nº 3.2) values. If it $qCO_2$ rises, it indicates a fall in microbial efficiency, which could be due to a stress factor ("e.g." a pollutant).

### 3.4. Soil-Compaction (MPa)

This is a similar measurement to "basic" indicator 3.2 (soil-penetrability), as it shows us the resistance offered by a soil to root penetration due to its compaction. This "advanced" production method requires the use of a digital penetrometer (Rimik CP40II) able to record (in MPa) the pressure needed to penetrate the soil over a 0-75 cm depth profile. 4 sampling points are selected within the study area and an average penetration (compaction) resistance value is obtained at each point from the results of the 5 bores. For grassy pastures, we compare the average penetration resistance value in the superficial 0-30 cm strata with the reference values in the advanced indicator table.

### 3.5. Soil-Acidity

The results of two measurements need to be taken into account when assessing this indicator:

• Measurement 1 – Aluminium-Al Saturation (%):

- Sampling and processing: See advanced indicator 2.3., but now the soil can be stored at ambient temperature.

- Laboratory analysis: The % Al saturation in the soil exchange complex is measured as per the standard MAPA method (1994). For more information, check our website: www.soilmontana.net

• Measurement 2 - pH:

- The sampling and processing methods are identical to those for Al saturation.

- Laboratory analysis: The soil pH is measured in water (1:2.5), as per the standard MAPA method (1994). For more information, check our website: www.soilmontana.net

Mountain pasture soils in rainy areas are typically acidic, due to the intense leaching of bases. This acidification, reflected by in a % increase in Al saturation (toxic for plants above 10%) and a fall in thel pH ("acid" below 7), significantly limits the development of plants and microorganisms.

3.6. Soil-N (%):

- Sampling and processing: See advanced indicator 3.5.

- Laboratory analysis: The total N content of the soil (Kjeldahl) is measured as per the standard MAPA method (1994). For more information, check our website: www.soilmontana.net

Nitrogen (N) is an essential macronutrient for plants and microorganisms in the soil.

3.7. Soil-P (ppm)

- Sampling: See advanced indicator 2.3.

- Processing: See advanced indicator 3.5 (dry soil).

- Laboratory analysis: The Olsen P content of the soil is measured, as per the standard MAPA method (1994). For more information, check our website: www.soilmontana.net

Phosphorous (P) is an essential macronutrient for plants and microorganisms in the soil.

3.8. Soil-K (ppm)

- Sampling: See advanced indicator 2.3.

- Processing: See advanced indicator 3.5 (dry soil).

- Laboratory analysis: The extractable K content of the soil is measured, as per the standard MAPA method (1994). For more information, check our website: www.soilmontana.net

Potassium (K) is an essential macronutrient for plants and microorganisms in the soil. However, in excess (as with N and P) it can lead to the eutrophication-contamination of running water downstream.

## 4. COMBATTING CLIMATE CHANGE

### 4.1. Climate change-$CO_2$ emission (g $CO_2$/$m^2$ h)

This measurement requires portable equipment (SRC-1 camera with an IRGA EGM-4, PP Systems®) for on-site measurement of the $CO_2$ emission rate of the soil. 4 sampling points are chosen in the study area and at each point we obtain an average $CO_2$ value from the 5 measurement results. Finally, we compare the average emission values with the reference values in the advanced indicator table.

Soils with low $CO_2$ emission rates help to slow down the climate change caused by atmospheric $CO_2$ accumulation.

### 4.2. Soil-Organic matter (%)

- Sampling: See advanced indicator 2.3.

- Processing: See advanced indicator 3.5 (dry soil).

- Laboratory analysis: The amount of oxidisable organic matter in the soil is measured, as described in MAPA standard method (1994).
For more information, check our website: www.soilmontana.net

Soils that increase their organic matter content are sequestering C from the atmosphere, thus combatting global warming.

## BAD RESULTS:
## What do they mean? How can I improve them?

Remember! keep it up even if your first measurements reflect bad health diagnosis, this may be due to poor grassland management in the past and/or even to local natural edaphoclimatic conditions. What is really important is that your ecosystem health improves year to year, thanks to your good practices.

| Service | Indicator "bad" | Meaning/consequences | Advice... |
|---|---|---|---|
| 1. Pasture production | - Low forage count | Infertile soil. | Fertilise and/or lime. |
| | - High animal rejection | Inappropriate pasture management. | Adjust livestock load and/or moment used. |
| | | Abundance of unpalatable and/or toxic species. | Cut rejected and/or eliminate unrequired species. |
| 2. Conservation of biodiversity (plant and animal) | - Low Nº of plant species | Loss of specific plant richness. | Reseed and manage correctly. |
| | - Low Nº of plant strata | Loss of structural plant diversity. | Protect trees and busshes. |
| | - Low Nº of macrofauna types | Impoverishment of trophic chain (high part). | Organic amendments and ensure plant cover. |
| | - Low Nº of mesofauna types | Impoverishment of trophic chain (med. part). | Organic amendments and ensure plant cover. |
| | - Presence of invasive species | Threat to autocthonous diversity. | Erradication and ensure plant cover. |
| | - Low functional microbial diversity | Low operational capacity of soil. | Organic supplements. Plant diversity. |
| | - Low genetic microbial diversity | Low resilience of soil. | Organic supplements. Plant diversity. |

| Service | Indicator "bad" | Meaning/consequences | Advice... |
|---|---|---|---|
| **3. Soil conservation** | - Low Nº of worms | Acidification. Means compaction. | Lime and/or organic supplements. |
| | - High soil compaction | Root development difficult. | Reduce livestock load. Organic amendments. |
| | - High % of bare soil | Overgrazing. Risk of erosion. | Reduce livestock load. Organic amendments. |
| | - Low infiltration capacity | Rain not made most of. Risk of erosion. | Reduce livestock load. Organic amendments. |
| | - Pale or parched vegetation | Lack of nitrogen and/or other nutrients. | Fettilise and lime. |
| | - Low microbial activity | Impoverished soil. Acidification? | Organic supplements. Lime? |
| | - Low microbial abundance | Impoverished soil. Pollution? | Organic supplements. Decontaminate? |
| | - High metabolic microbial quotient | Immature or stressed soil. | Organic supplements. Decontaminate? |
| | - pH too a) low | Acid soil. Plant growth limited. | Lime. |
| | b) high | Alkaline soil. Plant growth limited. | Sulfur. |
| | - N content too a) low | Limits development of plants and organisms. | Fertilise and/or lime. |
| | b) high | Risk of eutrophication downstream. | Adjust livestock load. Do not fertilise. |
| | - P content too a) low | Limits development of plants and organisms. | Fertilise and/or lime. |
| | b) high | Risk of eutrophication downstream. | Adjust livestock load. Do not fertilise. |
| | - K content too a) low | Limits development of plants and organisms. | Fertilise. |
| | b) high | Risk of eutrophication downstream. | Adjust livestock load. Do not fertilise. |
| **4. Combatting climate change** | - Low root abundance. | Low $CO_2$ sequestering capacity. | Do not tillage. Fertilise and/or lime. |
| | - Light coloured soil. | Low content of sequestered C in soil. | Do not tillage. Organic amendments. |
| | - High $CO_2$ emissions. | Accelerated loss of $CO_2$ to the atmosphere. | Do not tillage. Avoid bare soil. |
| | - Low organic matter content. | Low content of sequestered C in soil. | Do not tillage. Organic supplements. |

# BASIC Health Diagnosis

Plot name: _____ Date: _____

Land registry code (SIGPAC): _____

| Service | Basic indicators | Bad 1..2..3 | Average 4..5..6 | Good 7..8..9 | Indicator value (1-9) | Service value (1-9) |
|---|---|---|---|---|---|---|
| 1. Pasture production | 1.1. Fresh weight (kg/m$^2$ per year):<br>- mountain<br>- valley | <br><0,8<br><2 | <br>0,8-1,1<br>2-2,8 | <br>>1,1<br>>2,8 | | |
| | 1.2. Animal rejection (%) | >25 | 5-25 | <5 | | |
| 2. Conservation of biodiversity (plant and animal) | 2.1. Plant species (nº)<br>- mountain<br>- valley | <br><15<br><15 | <br>16-30<br>16-25 | <br>>30<br>>25 | | |
| | 2.2. Plant strata (nº) | 1 | 2 | 3 | | |
| | 2.3. Types of macrofauna (nº) | <3 | 3-6 | >6 | | |
| | 2.4. Invasive species (animal/plant) (nº) | >1 | 1 | 0 | | |
| 3. Soil conservation | 3.1. Worms (nº/m$^2$) | <16 | 17-64 | >65 | | |
| | 3.2. Compaction-penetrability (cm) | <3 | 3-15 | >15 | | |
| | 3.2'. Compaction- root depth (cm) | <15 | 15-30 | >30 | | |
| | 3.3. Erosion risk (% bare soil) | >15 | 5-15 | <5 | | |
| | 3.4. Infiltration capacity (min) | >30 | 10-30 | <10 | | |
| | 3.5. Plant colour | pale | patchy | dark | | |
| 4. Combatting climate change | 4.1. Root abundance | low | average | high | | |
| | 4.2. Soil colour | light | average | dark | | |
| BASIC DIAGNOSIS | | | | | | Final Mark |

# ADVANCED Health Diagnosis

Plot name: _____ Date: _____

Land registry code (SIGPAC): _____

| Service | Advanced indicators | Bad 1..2..3 | Average 4..5..6 | Good 7..8..9 | Indicator value (1-9) | Service value (1-9) |
|---|---|---|---|---|---|---|
| 1. Pasture production | 1.1. Dry weight (t/ha per year):<br>- mountain<br>- valley | <br><3<br><5,4 | <br>3-4,2<br>5,4-7,6 | <br>>4,2<br>>7,6 | | |
| 2. Conservation of biodiversity plant, mesofauna and soil microbiotics) | 2.1. Plant (H' diversity index)<br>- mountain<br>- valley | <br><1,5<br><1,3 | <br>1,5-2,5<br>1,3-2,3 | <br>>2,5<br>>2,3 | | |
| | 2.2. Mesofauna-types (index) | <40 | 40-70 | >70 | | |
| | 2.3. Functional fungi (H' diversity index) | <3 | 3-4 | >4 | | |
| | 2.4. Functional bacterias (H' diversity index) | <3 | 3-4 | >4 | | |
| | 2.5. Genetics fungi (nº species or bands) | <5 | 5-11 | >11 | | |
| | 2.6. Genetics fungi (nº species or bands) | <10 | 10-18 | >18 | | |
| | 2.7. Total genetics (H' diversity index) | <2 | 2-3 | >3 | | |
| 3. Soil conservation | 3.1. Microbial activity (mg C-$CO_2$/kg per hour) | <0,6 | 0,6-1 | >1 | | |
| | 3.2. Microbial abundance (mg C-$CO_2$/kg per hour) | <10 | 10-18 | >18 | | |
| | 3.3. Metabolic microbial quotient - q$CO_2$ | >0,1 | 0,1-0,06 | <0,06 | | |
| | 3.4. Compaction-penetrability 0-30cm (MPa) | >3 | 2-3 | <2 | | |
| | 3.5. Acidity - Al saturation (%)<br>Acidity - pH | >20<br><5 or >7,5 | 10-20<br>5-5,9 | <10<br>6-7,5 | | |
| | 3.6. N total (%) | <0,10 or >3 | 0,11-0,29 | 0,3-3 | | |
| | 3.7. Olsen P (ppm) | <8 or >45 | 8-15 | 15,1-45 | | |
| | 3.8. Extractable K (ppm) | <80 or >350 | 80-120 | 121-350 | | |
| 4. Combatting climate change | 4.1. $CO_2$ soil emissions (g $CO_2$/$m^2$ per hour) | >3 | 1,5-3 | <1,5 | | |
| | 4.2. Organic matter (%):<br>- mountain<br>- valley | <br><5<br><2 | <br>5-10<br>2-4 | <br>>10<br>>4 | | |
| ADVANCED DIAGNOSIS | | | | | | Final Mark |