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COMPARISON OF TWO ECOLOGICAL SUCCESSION MONITORING PROTOCOLS ON RESTORED ANDISOL

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ABSTRACT

The purpose of this study was to compare and contrast data from the stick and modified Braun-Blanquet monitoring protocols in three areas with different land use histories: an unrestored barren area, and both young and old revegetated areas. Vegetation and site characteristics were assessed at the three areas using the two protocols and soil sampling. The analysis of the data from the two protocols indicated a similar tendency, namely the improvement of the ecological condition of the restored areas compared to the unrestored area. The soil carbon and nitrogen content increased when the pH decreased with the age of restoration. The improvement was better in the old restored area which had received more fertilization compared to the young restoration area. The stick method estimated a greater cover of vascular plants, litter, mosses and rocks, and a lower amount of bare ground than did the modified Braun-Blanquet protocol. The two protocols provided similar estimates for lichen and sedge cover. The stick method also provided three supplementary indicators which were not included by the modified Braun-Blanquet: plant base, basal and canopy gaps. Another observation that could be proved by further studies was that the stick seemed to be more precise and more economical in time than the modified Braun-Blanquet. The indicators provided by the two protocols were related to the three attributes of ecosystems and the rangeland health indicators. This study was preliminary and the results cannot lead to recommendation of one method over the other, but the results do indicate a preference for the stick method to assess and monitor vegetation dominated by an understorey layer and for the modified Braun-Blanquet for areas dominated by a woody layer.

Key-words: ecological restoration, assessment, stick method, modified Braun-Blanquet protocol, generalized linear model, multivariate analysis, Iceland

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1. INTRODUCTION

Increased human activities continue to dramatically shape the surface of the Earth, with severe effects on natural systems. Changes in ecosystems include soils, biodiversity and their resilience in the face of various disturbances which reduce their capacity to provide services that support human well-being (MEA [Millenium Ecosystem Assessment] 2005). One of the supporting services is to regulate the carbon fluxes in the atmosphere; this function is becoming more attractive because of its potential to contribute to the mitigation of climate change (Lal 2004b; Howell et al. 2012).

Reversal of the current trend of degradation necessitates the understanding of ways to manipulate ecological processes which can rapidly direct succession to favour ecological conditions. Ecological restoration is the process by which degraded ecosystems are assisted to return to their original or favourable state and re-establish self-regulatory natural functions (SER 2004; Hobbs & Cramer 2008; Howell et al., 2012; Galatowitsch, 2012). Hence, restored ecosystems help to stabilize soil erosion and natural systems, enhance biodiversity and increase the rate of carbon sequestration from the atmosphere (Silver et al. 2000; Lal 2004a). In practice, restoration is based on natural processes such as ecological succession (Parker & Pickett 1997; Walker & Del Moral 2003; Walker et al. 2006; Raevel et al. 2012). Natural succession on degraded lands can be a slow process and therefore manipulation of succession processes often aims to accelerate the recovery process. This may involve soil treatments, seeding or planting trees among others, thus changing the conditions of the degraded site and initiating autogenic repair (Aradottir & Hagen 2013). The starting point for manipulating depends on the condition of the degraded site; each site requires particular methods and their proper timing to manipulate succession toward a desired target (Prach et al. 2007). Accordingly, it is important to understand how succession operates, and when and how to manipulate it.

Generally, assessment and monitoring of land condition and changes are based on vital attributes of ecosystems, such as plant composition or soil stability as surrogates for rangeland condition or livestock carrying capacity, but restoration projects seek to repair processes rather than replace species or nutrients (Pellant et al. 2005; Ruiz-Jaen & Mitchell Aide 2005). Assessing short-term plant composition is necessary, but not enough to predict long-term sustainability (Herrick et al. 2006b). Since the resilience of the restored site depends on the recovery and the maintenance of ecological processes, it is crucial to base the assessment on them. Ecological processes, including soil stability, fully functional hydrologic processes, the integrity of nutrients cycles and energy flows are all key attributes for sustainability and biotic integrity of a given site (Whisenant 1999; Pyke et al. 2002; Herrick et al. 2006a; Herrick et al. 2006b; Toevs et al. 2011; Herrick et al. 2012). But ecological processes are difficult to assess due to their complexity and the interactions among them (Pellant et al. 2000). Quantifiable biological attributes (plant cover and composition, functional groups cover and composition, biological crusts, etc.) and physical attributes (soil stability, percentage of bare ground, rocks, etc.), which are correlated with key attributes of ecosystems, are generally assessed and monitored as indicators of ecological processes and site integrity. Several protocols, including the modified Braun-Blanquet and line-point intercept methods or recently the stick method, give measures that are used as indicators of some ecosystem attributes (Pellant et al. 2000; Ludwig et al. 2004; Tongway & Hindley 2004; Herrick et al. 2005; Pellant et al. 2005; Riginos & Herrick 2010). The modified Braun-Blanquet protocol for sampling vegetation is adapted from the Zurich -Montpellier school of phytosociology, one of the classic methods of studying vegetation (Braun-Blanquet 1932). The Braun-Blanquet protocol, even though it has been challenged as being subjective (Egler 1954), is still widely used and is argued to represent a scientifically sound, versatile and efficient assessment method in botany (Werger 1974). It was developed to identify and describe plant communities, used to monitor effects of changes on plant species within these communities, and to assess restoration or reclamation success of disturbed plant communities (Bonham et al. 2004). The stick method is a modification of the line-point intercept method, developed in context with a monitoring tool for rangeland assessment (see Riginos & Herrick 2010). This protocol is suggested for rangeland assessment; it seems to be precise, easy to learn and to apply, and to provide easily attributes that relate to productivity, infiltration or runoff and soil loss. Different studies have been carried out to describe several assessment protocols and show their strengths and weaknesses (Fehmi; Stohlgren et al. 1998; Prosser et al. 2003; Carlsson et al. 2005; Godínez-Alvarez et al. 2009). This study was proposed to determine the differences between the protocols described above and how the indicators they provide can be linked to the ecological status of given lands.

Over the years, Iceland has faced severe land degradation due to the sensitivity of the soil to erosion, deforestation and overgrazing by sheep (Arnalds et al., 2001). This situation was aggravated by the cooling climate and drifting sand, which led to extensive desertification. Today, about 40% of the total area of the country is classified as having moderate to severe erosion (Arnalds et al. 2001). The Soil Conservation Service of Iceland (SCSI) was established in 1907 to struggle against soil erosion. Since then, SCSI has carried out intensive restoration activities and research in order to stop soil erosion and restore degraded lands. The SCSI also assists farmers in managing and improving their land resources. Thus, different forms of collaborations including "Farmers Heal the Land" and "Land Restoration groups" were established between the farmers and the SCSI. In the "Farmers Heal the Land" project, for example, farmers apply for participating and the District Consultants visit them and see if they fulfil the requirements for participating. If the farmer is accepted in the project, he gets grants that will cover 85% of the fertilizer cost (S. Jónsdóttir, 3 September 2013, Soil Conservation Service of Iceland, personal communication). If seeds are needed, they are provided by the SCSI. The amount of fertilizer is pre-determined and is variable between farmers according to how large an area needs revegetation, how much area the farmer is able to cover in each year and how much the SCSI can afford. The restored areas are monitored by District Consultants from the SCSI. For the monitoring of the revegetated areas, the District Consultants visit the farmer's land on a regular basis to collect information that is kept in a database at SCSI. During these visits the District Consultants and the farmers discuss the condition of the land and suggest solutions as needed. This assessment, based as it is on simple discussion even if it allows learning from each other, cannot offer a measurement of the biological and physical attributes that describe the ecological status of the revegetated lands. It is important for the "Farmers Heal the Land" project to find such a protocol that can be used to assess and monitor the revegetated lands. Results from these evaluations can be used to adjust or modify management strategy. Such a protocol needs to be simple to apply and give reliable data that reflect the ecological status of the land.

This study intended to compare the two protocols, the stick method and the modified Braun-Blanquet, for assessing the ecological status of land that has been revegetated within "the Farmers Heal the Land" project. Specifically, the purposes of the study were to: (1) compare and contrast the two monitoring protocols in three areas with different land use histories: an unrestored barren area, a young revegetated area and an old revegetated area, located within the same ecological site; (2) assess the succession trend in the three areas; (3) relate the indicators provided by the two protocols to the three key attributes of ecosystems and the

Rangeland Health Indicators (RHI) for interpretation; (4) and evaluate the relevance of these simple indicators for sustainable land management.

2. MATERIAL AND METHODS

2.1 Study area

The study was conducted in southern Iceland (Fig. 1), 20 m above sea level, in three areas with similar environmental characteristics and different land use histories: (1) an unrestored area, (2) a young revegetated area (three years old) located at Varmadalur, and (3) an old restoration area (seven years old) located at Selalækur (Fig. 2). The treatments of the revegetated areas were done by fertilization of about 200 kg/ha of inorganic NP (25 : 6). The three year old restored area had received three applications of fertilizer and the seven year old restored area four applications. The climate of south Iceland close to the study area is oceanic-boreal with a mean temperature for 1958 to 2004 of -1.6°C in January and 11°C in July, and a mean annual precipitation of 1.218 mm (Icelandic Meteorological Office, unpublished data from Hella weather station). The soils of Iceland, mostly Andosols (WRB; Vitric Andosol) or Andisols (Soil Taxonomy; Vitricryand), formed on volcanic deposit lava were exposed to wind and water erosion (Arnalds et al., 2001, 2013). The cumulative effect of natural disturbances such as the cooling weather, the active volcanos, increased aeolian deposits and human activities like deforestation and overgrazing added to the susceptibility of the soil to erosion and amplified the degradation (Arnalds 2000). The soil surface of the study area is typical gravelly sand classified as lag gravel (Arnalds et al., 2001). The lag gravel soil seems to result from the degradation of the birch woodlands and willow shrublands, which were the original vegetation of Iceland at the time of settlement (Gunnlaugsdottir 1985).

Fig 1. *Location of the study in south Iceland; 1 = unrestored area, 2 = young restored area (3 years old) and 3 = old restored area (7 years old).*

2.2 Sampling design

Vegetation and site characteristics were assessed at four randomly selected points in each area. From each pre-determined point, four transects of 25 m were established in the direction of the four cardinal points for vegetation and site characteristics surveying using the stick method of assessment. At each pre-determined point, a 10 m × 10 m plot was established in the north-east quadrant. Five 0.25 m² quadrats were randomly selected within the plot for vegetation and site characteristics surveying using the modified Braun-Blanquet protocol (Fig. 3).

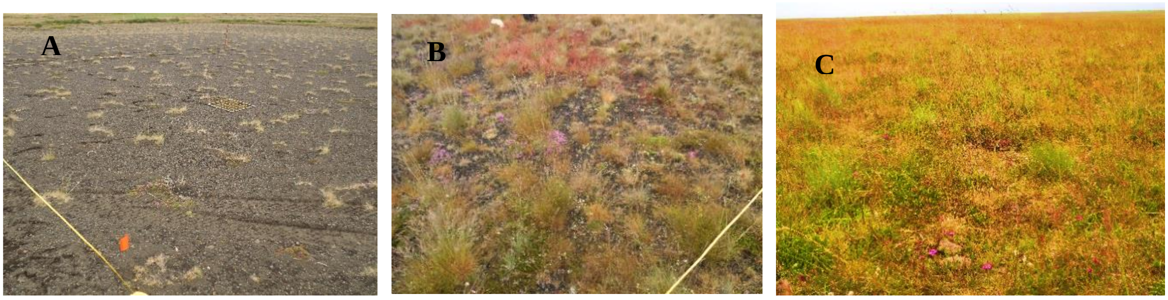


Fig 2. *Cover of plants and bare ground in the three study areas: A = unrestored area, B = young restored area (3 years) and C = old restored area (7 years). (Photos: I. Soumana, 9-12 July 2013).*

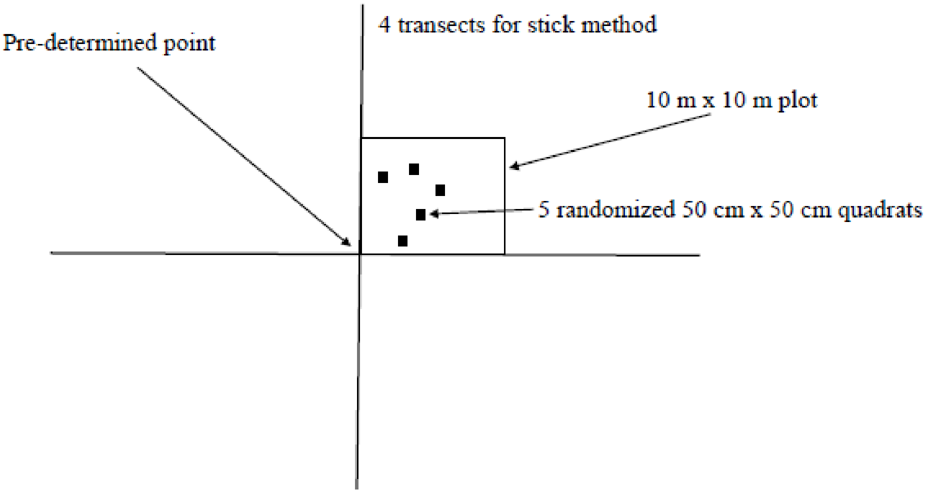


Fig. 3. *Placement of the transects for stick method and the 10 m × 10 m plot for modified Braun-Blanquet relative to each of the predetermined points.*

2.3 Sampling vegetation and site characteristics with the stick method

Along the four transects of each pre-determined point, a stick one meter in length was laid systematically on the ground at every five meters for recording vegetation and environmental variables. Foliar cover of plant functional groups along the 1-m stick were assessed by dropping a metal rod of one mm diameter vertically towards the soil at every 20 cm and all shrub, grass, forb, sedge, moss and lichen that were contacted by the rod were recorded, for a total of 25 points/transect and 100 points/predetermined point. At the soil surface, contacts of the rod with the plant base, litter, bare ground and rock; and base and canopy gaps through the stick were recorded. The total height of the vegetation which covered the stick was also estimated visually (Riginos & Herrick 2010).

2.4 Sampling vegetation and site characteristics with the modified Braun-Blanquet

The Braun-Blanquet five levels of abundance have subsequently been modified into six, eight or ten levels by splitting one, two or three scales in order to improve the accuracy of the estimated data (Daubenmire 1959; van der Maarel 1979). In this study, plants functional groups were estimated in quadrats of 0.25 m² using the following eight cover classes: 1 = <1%; 2 = 1–5%, 3 = 6–10%; 4 = 11–15%; 5 = 16–25%; 6 = 26–50%; 7 = 51–75%; and 8 = 76–100%. The cover of total plants and other vegetation, percentages of bare ground, rock, litter and the height of the tallest branch were also recorded. The two protocols provide measurement of similar indicators, but the modified Braun-Blanquet does not include measures of plant bases, basal and canopy gaps that are included in the stick method.

2.5 Soil sampling

Soils were sampled in the centre of each 0.25 m² quadrat, with an auger, to a depth of five cm, and then the five samples from each quadrat were mixed to make a composite sample. Soils were dried at 30ºC and passed through a 2 mm sieve to prepare them for analysis. Additionally the soil samples were checked for moisture content at the time of analysis for adjusting results. Total carbon (g/kg) and nitrogen (g/kg) were determined by dry combustion using a Vario Max C/N-Macro Elemental Analyser. Soil pH was measured with electrodes in a 1:5 soil-water suspension (Blakemore et al. 1972).

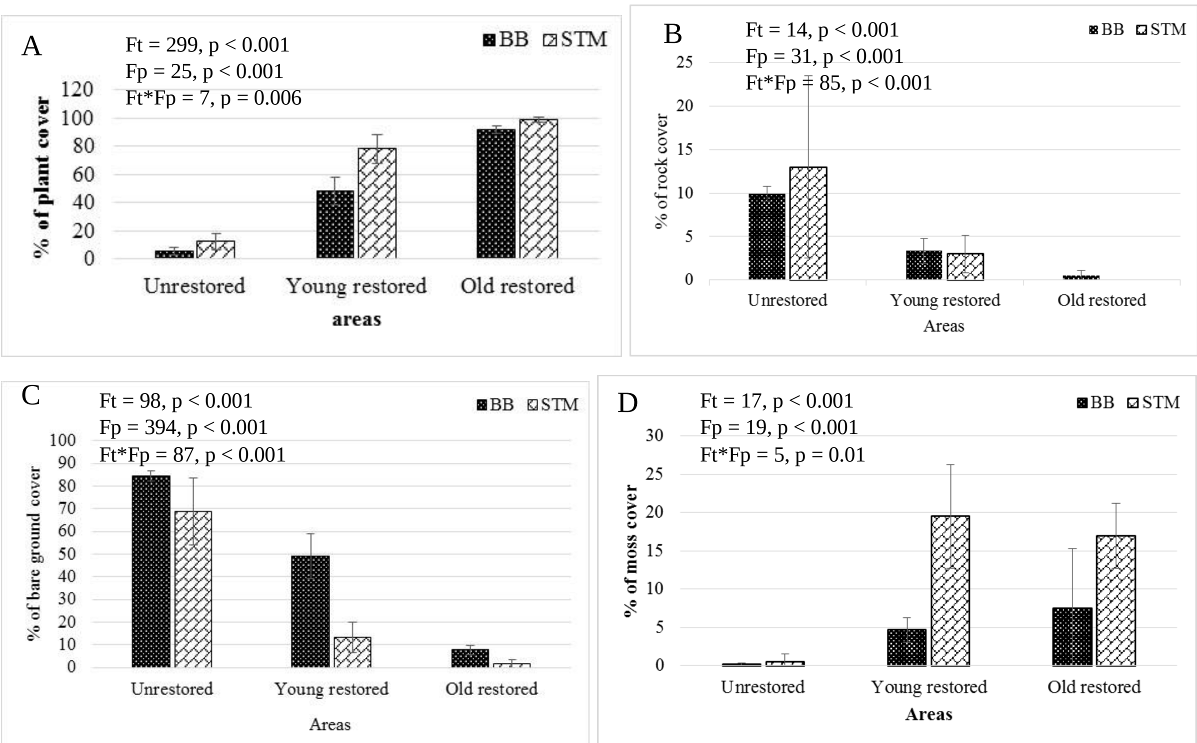
2.6 Data analysis

Statistical analysis was done on the mean cover of total vascular plants, functional groups, litter, rocks, bare ground, plant bases and basal gaps recorded in the three treatments. Before analysis, the cover scores from the modified Braun-Blanquet were transformed to percentages by using the central value of each cover class and averaged over all the five quadrats of each 10 m × 10 m plot (cf. Aradottir, 2012). The amount of shrubs, grasses, forbs, sedges, mosses and lichens, base, litter, bare ground, rock, base and canopy gaps recorded on transects by the stick method were also averaged for each pre-determined point. Thus, there were four data points for each protocol in each area (treatment), for a total of 12 points. The pooled data from the two protocols were used to test for effects of assessment protocol, restoration age (treatment) and their interaction by analysis of variance (ANOVA, Generalized Linear Model) where restoration age was nested within the sample areas. Correlation between measurements by the two protocols was also analysed using the Pearson (r). For the use of Analysis of Variance (ANOVA) and the Pearson correlation, the normalities of the pooled data were tested by using the Kolmogorov-Smirnov test. When the normality and equal variances were not met, the data were $\ln(x + 1)$, $\ln x$, square root or ASINH transformed. Transformation by $\ln(x + 1)$ was used for the amount of rock and bare ground, $\ln x$ for litter cover, square root for sedge cover and ASINH for moss, lichen, grass, forb and shrub covers. One way ANOVA was used to test the differences in soil pH, total nitrogen and carbon content, and C/N ratio among treatments (restoration ages). The ANOVAs, normality and correlation tests were done with Minitab v.14. (Dytham 2011). Principal Component Analysis (PCA), a multivariate test which weights the variables to maximize differences between individuals (Dytham 2011), was used to visualize the differences between the two protocols in ordination space. PCA was also done separately on the two data sets to observe how well they reflected differences in functional groups cover and composition and changes in site characteristics. In the PCAs, grass, forb, sedge, moss, shrub and lichen cover were used as variables of plant abundance. The PCAs were done using PC-ORD v.5.0 (McCune & Grace 2002).

3. RESULTS

3.1 Variation in functional groups abundance and site characteristics with increased restoration age and between protocols

GLM analysis done on the pooled data revealed significant effects of protocol types, restoration ages and their interaction for cover of total plants, rock, bare ground, mosses, litter, grasses, forbs and shrubs (Fig. 4). The modified Braun-Blanquet protocol yielded a significantly lower cover of total plants, rock, mosses, litter, grasses, forbs and shrubs for all the treatments ($p < 0.001$) compared to the stick method. On the other hand, the stick method gave a significantly lower cover of bare ground for all three treatments ($p < 0.001$) compared to the modified Braun-Blanquet. In contrast, there were no significant effects ($p > 0.05$) of protocols, restoration ages, and their interaction for cover of lichen and sedge excepted for lichen, which showed a significant effect only for restoration ages ($p = 0.006$). In fact, for all the treatments, the stick method seemed to capture more vegetation, plant functional groups, rock, and litter; and the modified Braun-Blanquet appeared to be more sensitive to bare ground. Compared to the unrestored area, the two protocols revealed a significantly higher cover of total plants, mosses, litter, grasses, forbs, lichens and shrubs and a significantly lower cover of bare ground and rocks at the restored areas with increased age of the restoration treatment. Only the sedge cover was not different between the three areas and the two protocols. In fact, despite the variation in cover estimates of plants and site characteristics, the two protocols showed similar tendencies.



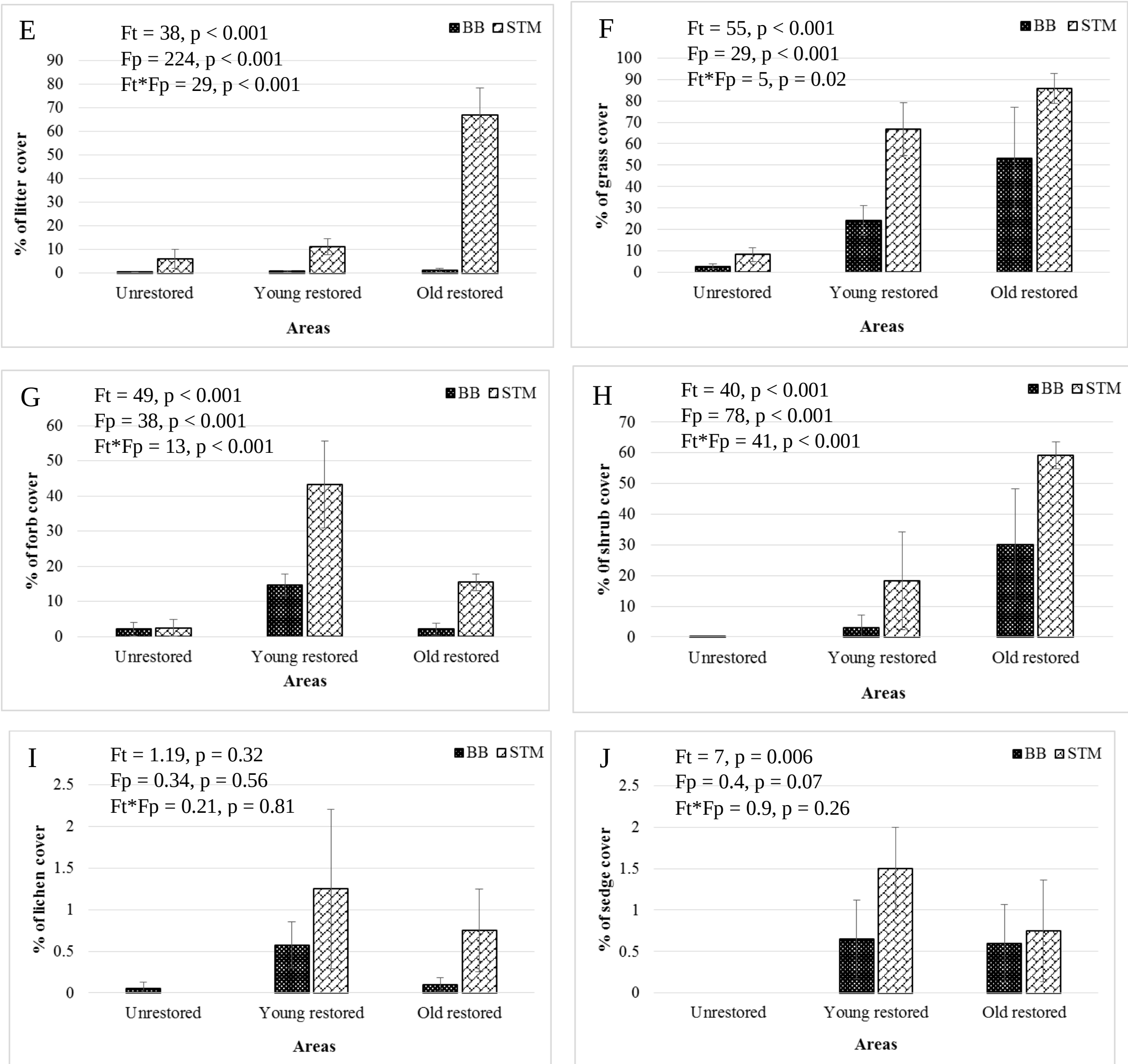


Fig 4. *Estimated cover (mean and standard error) of (A) total plants, (B) rocks, (C) bare ground, (D) moss, (E) litter, (F) grass, (G) forb, (H) shrub, (I) sedge and (J) lichen in different study areas for stick method (STM) and modified Braun-Blanquet protocol (BB). Results from nested ANOVA on protocol types (Fp), restoration (treatments)(Ft) and their interaction (Ft×Fp) for each cover (A-J). When p < 0.05 the effect is significant.*

3.2 Ordination of the vegetation data

The two first axes of the PCA ordination of pooled data from the stick method and the modified Braun-Blanquet assessment explained cumulatively 86.81% of the variance (Fig 5). In the graph, only plots recorded in the unrestored area were located in the same place; the other plots were scattered in the ordination space. Thus, data from the unrestored and restored areas showed respectively high homogeneity and variability of vegetation cover with samples, between treatments and protocols.

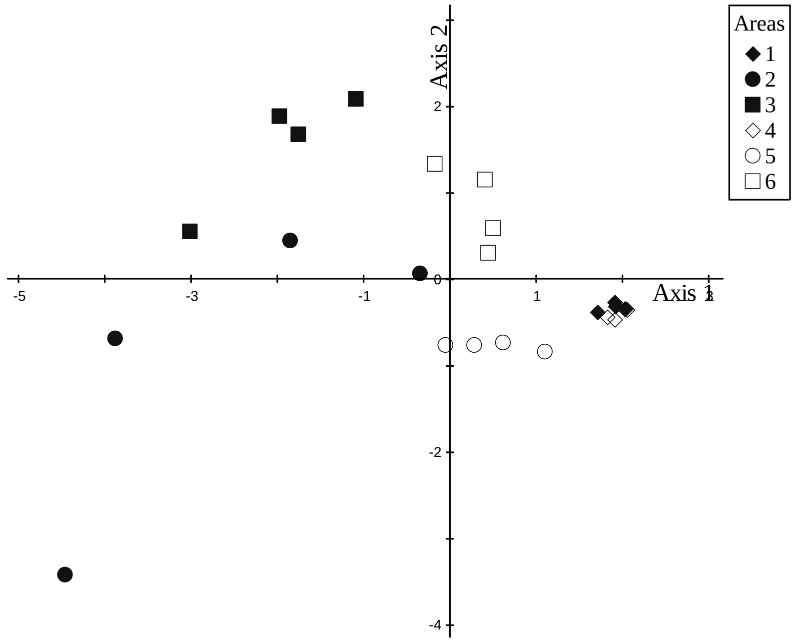


Fig 5. *Principal components ordination from pooled data, stick method (filled plots) and Braun-Blanquet (empty plots), diamonds = unrestored plots, circles = young restored plots and boxes = old restored plots; Eigenvalue and variance of axis 1 are respectively 0.79 and 61%, and eigenvalue and variance of axis 2 are 0.12 and 21%.*

Axis 1 of the two PCAs of the stick method and the modified Braun-Blanquet when analysed separately (Fig. 6) explained, respectively, 61% and 36% of the total variances. The two graphs reveal a similar tendency; plots from restored areas versus the unrestored area were separated along axis 1 and distinctly reflected a recovery gradient. Analysis of the data from the stick method PCA (Fig. 6A) showed strong positive correlations between axis 1 and total plant cover, height, plant bases, litter, carbon, nitrogen and C/N ratio. Strong negative correlations were observed between the same axis and rocks, bare ground, basal gaps and pH. Similar correlations were observed between the factorial axis and environmental variables in the modified Braun-Blanquet PCA (Fig. 6B). Axis 1 of both ordinations was interpreted as a gradient of recovering plant cover, height and base, carbon and nitrogen content, C/N ratio and litter, and a lowering of pH, rocks and bare ground.

3.3 Comparison of the two protocols

A strong correlation was observed between the stick method and the modified Braun-Blanquet protocols for cover of total vegetation ($r = 0.95$), rocks ($r = 0.86$), bare ground ($r = 0.91$), mosses ($r = 0.87$), grasses ($r = 0.93$) and forbs ($r = 0.73$). On the other hand, there was no relationship between the protocols for estimates of shrub, sedge, lichen and litter cover. Comparison between the stick method and the modified Braun-Blanquet protocols (Fig. 7) showed only similar cover estimates for sedge and lichen. The stick method gave higher cover values for total plants, rocks, grasses, mosses, litter, forbs and shrubs than did the modified Braun-Blanquet. On the other hand, modified Braun-Blanquet tended to estimate a higher bare ground cover than did the stick method.

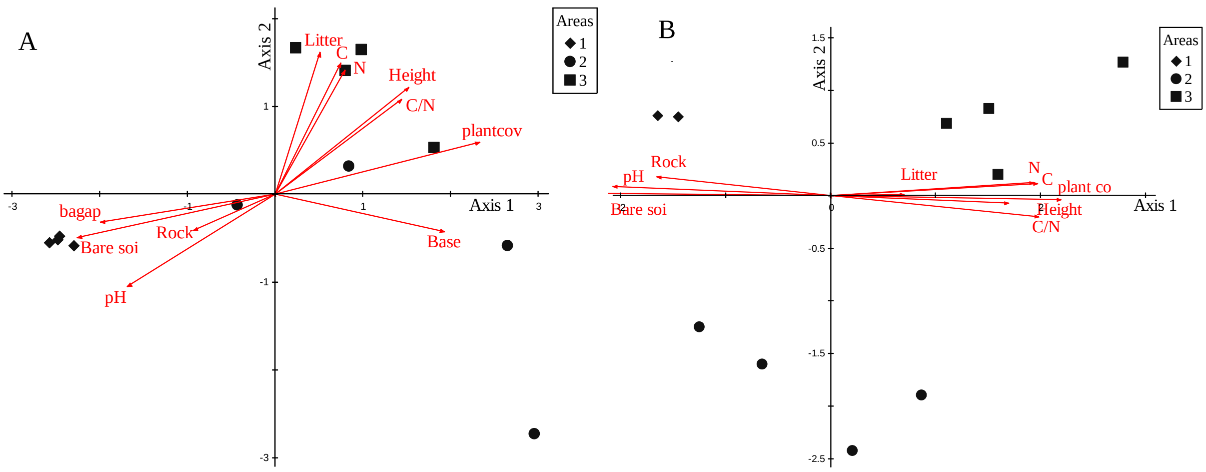
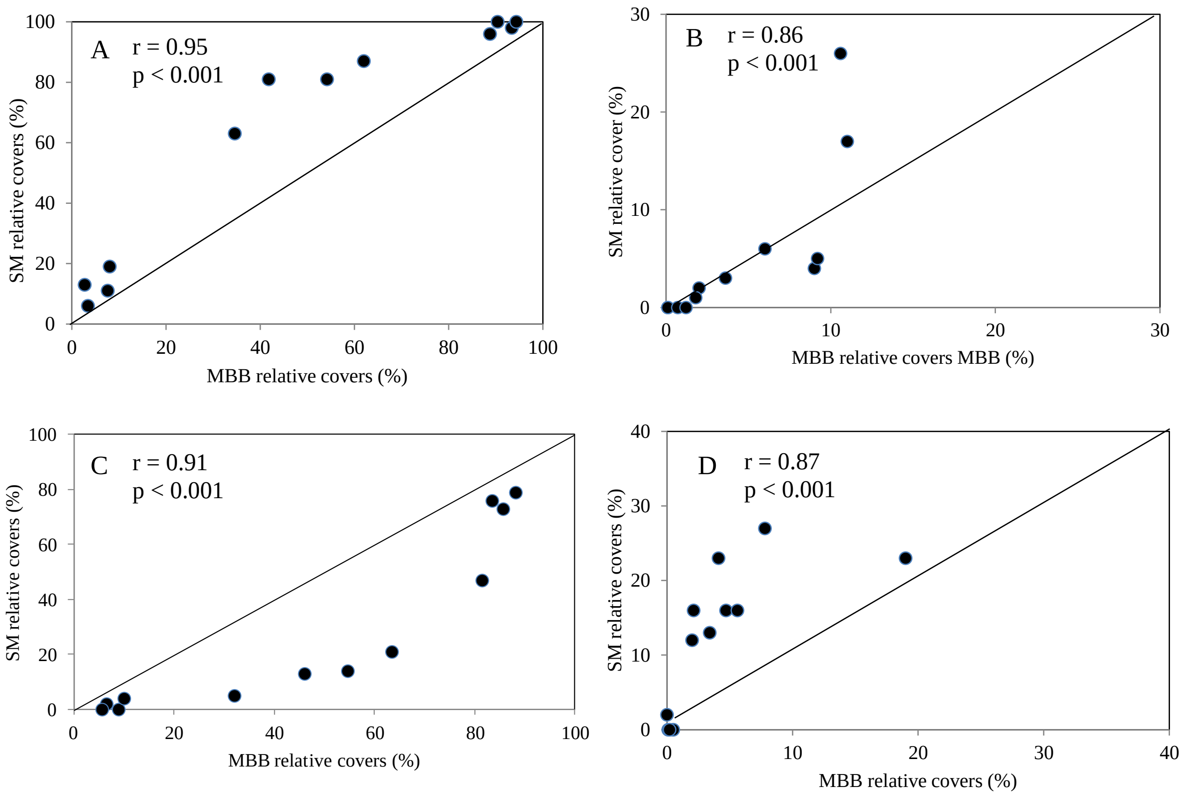


Fig. 6. *Principal components ordinations of stick method and modified Braun-Blanquet data: A = PCA with stick method; B = PCA with modified Braun-Blanquet; diamonds = unrestored plots, circles = young restored plots and boxes = old restored plots; Graph A: Eigenvalue and variance of axis 1 are 0.79 and 63%, and eigenvalue and variance of axis 2 are 0.19 and 31%; Graph B: Eigenvalue and variance of axis 1 are 0.71 and 36% and eigenvalue and variance of axis 2 are 0.24 and 29%.*



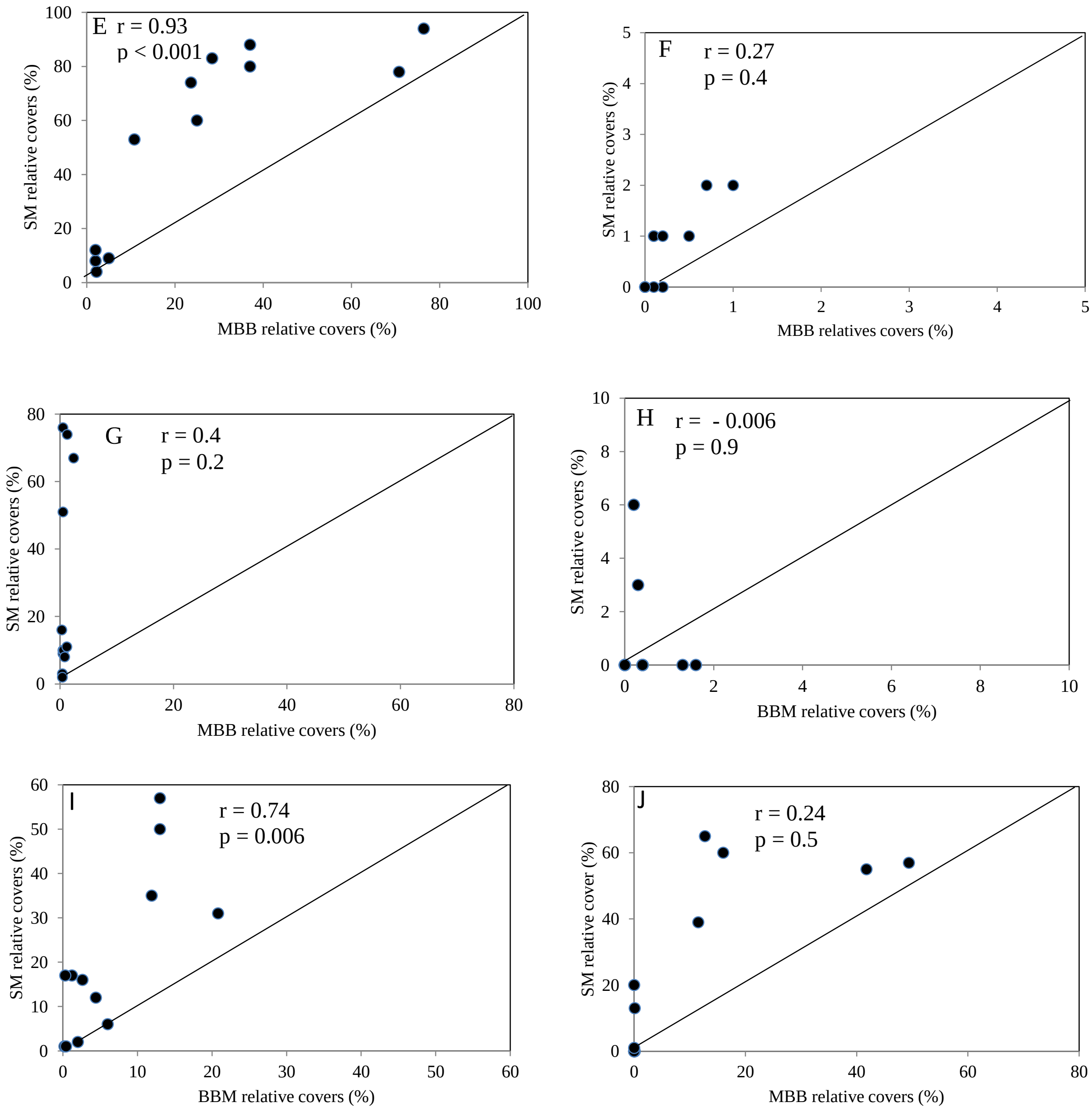


Fig 7*. Pearson (r) correlation between average cover per point measured by the stick method (SM) and the average cover per point for the modified Braun-Blanquet (MBB) protocol for (A) total plant, (B) rock, (C) bare ground, (D) moss, (E) grass, (F) lichen, (G) litter, (H) sedge, (I) forb and (J) shrub; when $p < 0.05$, the correlation is significant.*

3.4 Effects of restoration activities on soil properties

Compared to the unrestored area, soil carbon (C) and nitrogen (N) content and the C/N ratio increased significantly with restoration age while pH decreased significantly with restoration ages ($p < 0.001$) (Fig. 8).

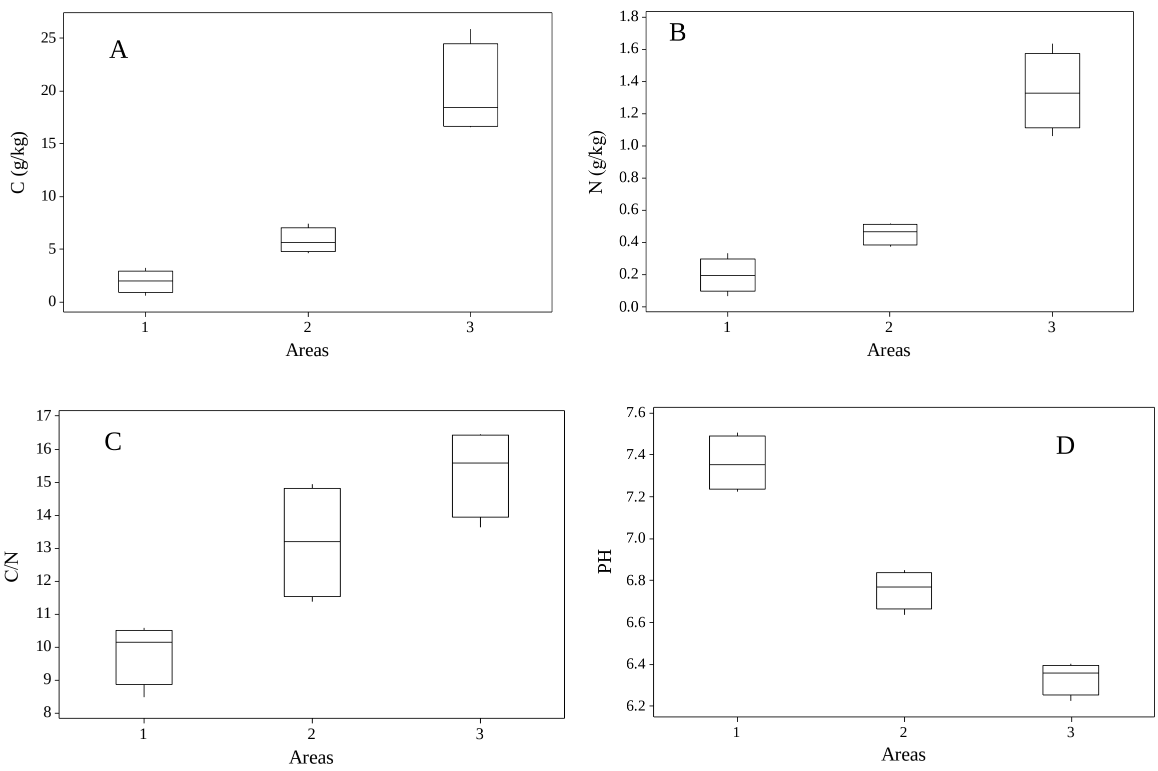


Fig. 8. *Variation of soil properties shown in box plots between the three areas; 1 = unrestored, 2 = young restored, 3 = old restored; Carbon (A), Nitrogen (B), C/N ratio (C) and pH (D); dash in box = median; the interquartile range = minimum and maximum*

4. DISCUSSION

4.1 Successional trend and interpretation of the quantitative indicators

Compared to the unrestored area, the restored areas' condition was changed by the restoration action, which led to an increase in the cover of vascular plants, lichens and mosses, plant bases, litter, soil carbon and nitrogen content, and C/N ratio and a decrease in the cover of bare ground, rocks, basal gaps and soil pH. When the carbon and the soil contents were increasing with the restoration age in the restored areas, the pH was decreasing. The quantitative indicators indicated the recovery of the fertilized areas. The differences between the three areas could be attributed to the age of restoration and the number of fertilizer applications. The abiotic and biotic conditions of the unrestored area can also constrain seedling survival and plant growth (Elmarsdottir et al. 2003). Fertilization may remove the constraints by improving the soil fertility in the restored areas. This may enhance the stability and improve the hydrological functions of the soil, which may facilitate the turnover of the species that increase plant productivity through the availability of safe microsites and the capture of wind-blown seeds (Gretarsdottir et al. 2004). Plant biomass production may increase the foliar cover of vascular plants and base as well as litter production that reduces the area of bare ground and the amount of rocks. The enhancement of foliar cover of vascular plants can create a microclimate that can allow the establishment and the expansion of the understorey layer such as lichen and moss. According to Elmarsdottir et al. (2003), application of fertilizer without additional seeding on degraded lands can enhance favourable microsite availability and the turnover of native species and expand plant cover. Site treatments such as seeding, planting turfs, fertilizing, organic mulching or soil physical treatment were known to accelerate succession by improving biotic and abiotic conditions of degraded lands (Aronson et al. 2006; Prach & Hobbs 2008; Řehounková & Prach 2008; Aradottir 2012).

Sustainability of the restored area depends on the recovering of the biotic integrity, hydrological functions and soil stability (Herrick et al. 2012). These attributes are the foundation of resilience, i.e. the capacity of the site to recover after perturbation (Holling 1973). The simple quantitative indicators can be measured as surrogates to the attributes of resilience and the rangeland health indicators (RHI) (Pellant et al. 2005; Riginos & Herrick 2010; Kachergis et al. 2011) (Table 1). Biotic integrity as surrogate to energy capture and nutrient cycling can be simply measured by for example, the cover of plants, lichens and mosses, and the soil carbon and nitrogen content; hydrological functions can be simply measured by for example, cover of bare ground, rocks, and basal gaps; soil stability can be estimated by, for example, plant cover, litter distribution, and soil carbon and nitrogen content. Therefore, the restored areas with their high cover of vascular plants, lichens and mosses and high content of nitrogen and carbon had a great biotic integrity. These also infer a low bare ground, basal gaps and rocks cover which address improved hydrological functions and soil stability. Some of the indicators can act for more than one attribute, e.g. a degraded area with a high cover of bare ground allows water flow and soil loss, which in turn reflects low foliar cover and infers reduced soil stability and biotic integrity. Accordingly, the quantitative indicators can be assessed to address nearby ecosystem functions. This information may probably include other factors such as biodiversity, plant mortality, soil condition, and nutrient and energy fluxes that are likely to address future changes. Herrick et al. (2012) suggested using these simple indicators, which reflect both earlier and future changes, to monitor short and long term effects of management. This information could be extrapolated to a large area by using remote sensing and Geographic Information System (GIS) tools. Such simple indicators are needed for assessment and monitoring because they can act for more than one attribute of ecosystems and cover a large landscape (Ludwig et al. 2004). Temporal measurements of these indicators can also be stocked in a database and integrated in conceptual models such as state and transition model (S & T) to guide land management by identifying thresholds and trends and adjusting strategies (Karl & Herrick 2010).

4.2 Comparison of the two monitoring protocols

Similar trends were observed in the recovery of the restored areas when data from monitoring protocols were analysed separately. Both protocols showed greater plant foliar cover and base, functional group abundance, soil carbon and nitrogen content and C/N ratio, and a lower bare ground, rocks, plants basal gaps and soil pH in the restored areas. Consequently, the indicators revealed the gradual improvement of the ecological condition of the restored areas, which was better at the old restoration area than at the younger restored area. Analysis of the pooled data showed variations of assessment data between the three treatments, samples and the two methods despite the surveying of the same areas. These variations could be attributed to the difference in the data provided by the two protocols. Compared to the modified Braun-Blanquet, the stick method gave a lower cover of bare ground while the modified Braun-Blanquet tended to give a lower cover of total plants, litter, mosses, shrubs, forbs, grasses, lichens, and litter (Fig. 4). This variation could also be attributed to the difference in the sampling locations at the same pre-determined point, but variation between protocols and plots could be more important than between surveying locations (Anderson & Fehmi. 2005).

Moreover, plants were recognized as having spatial patterns rather than being distributed uniformly. In fact, changes in surveying location could allow a change in vegetation data in the same plant community (Carlsson et al. 2005). Observer behaviour in placing the sample and the rod, following the transect, and visual estimation level (Tonteri 1990) could also affect the data. The experience of the observer in sampling vegetation has been shown to improve the accuracy of the data (Kercher et al. 2003; Carlsson et al. 2005; Milberg et al. 2008).

Table 1*. Assessment protocols, quantitative indicators, key attributes of ecosystems, and Rangeland Health Indicators (RHI) (Pellant et al. 2005; Riginos & Herrick 2010); HF = hydrologic function, SS = soil stability, BI = biotic integrity.*

	key attributes of ecosystems						
Assessment protocols	Stick method			Modified Braun-Blanquet			
Quantitative Indicators	HF	SS	BI	HF	SS	BI	Rangeland Health indicators
% Total vascular plants cover	√		√	√		√	Bare ground, annual production, gullies, plant mortality, number of function groups, plant communities, water flow
% Bare ground	√	√			√	√	Rills, water flow, pedestals, gullies, wind-scoured areas, blowouts or deposition areas, litter movement, bare ground, soil resistance to erosion, soil loss and compaction layer, litter movement
% Plant base	√	√					Soil resistance to erosion, soil loss, invasive plant, compaction layer, litter amount, annual production, invasive plant, reproductive capability of perennial plants.
% Litter	√	√	√	√	√	√	Soil resistance to erosion, soil loss, compaction layer, plant mortality, litter amount, annual production, plant mortality, litter amount, productivity, invasive plants, reproductive capability of perennial plants.
% Rock	√	√		√	√		Water flow, pedestals, bare ground, wind-scoured areas, blowouts or deposition areas, soil resistance to erosion, soil loss and degradation
% Basal gaps	√	√	√				Rills, water flow, pedestals, gullies, wind-scoured areas, blowouts or deposition areas, litter movement, bare ground, soil resistance to erosion, soil loss and compaction layer, litter movement
% Plant compositions	√		√	√		√	Annual production, plant mortality, function groups, plant communities, invasive plants, reproductive capability
% Functional groups	√		√	√		√	Soil resistance to erosion, soil loss, compaction layer, plant mortality, litter amount, annual production, plant mortality, litter amount, productivity, invasive plants, reproductive capability of perennial plants
% Lichen	√	√	√	√	√	√	Biological soil crusts distribution and degree of development
% Moss	√	√	√	√	√	√	Biological soil crusts distribution and degree of development
% Grass cover	√		√	√	√		Above ground production, water flow, soil surface loss, soil resistance to erosion, compaction layer, litter movement

As the two protocols provided similar tendencies, they led to a comparable interpretation of the data. Hence, the differences observed should be considered as bias that could be linked to the differences between the two protocols and the spatial variability of the vegetation. These factors could interact and influence the precision of the data. Studies to compare the accuracy of ocular estimation of cover such as the modified Braun-Blanquet, Daubenmire and modified Whittaker plots, etc. to other methods of surveying vegetation (Kercher et al. 2003; Leis et al. 2003; Anderson & Fehmi. 2005; Godínez-Alvarez et al. 2009; Laliberté et al. 2010) have shown that ocular estimation can lower estimated plant cover, but it seems to have a great potential to detect maximum species in the assessed areas compared to the line-point intercept. Consequently, ocular estimate methods seem to be good to monitor and assess biodiversity (Stohlgren et al. 1998; Godínez-Alvarez et al. 2009). Ocular estimate methods also seem to be more consistent for assessing shrub cover than the line-point intercept protocol (Brun & Box 1963; Floyd & Anderson 1987). Research by Godínez-Alvarez et al. (2009) supports the use of ocular estimates to assess vegetation dominated by shrubs. The stick method is a modification of the line-point intercept. Compared to ocular estimation methods, the line-point intercept seems to be more precise in measuring foliar cover

(Godínez-Alvarez et al. 2009; Kercher et al. 2003). Accordingly, the stick method may also be more accurate in estimating the cover of vascular plants, lichens, mosses, rocks and litter than the modified Braun-Blanquet. It provides three supplementary indicators which are not available using the modified Braun-Blanquet: basal and canopy gaps, and plant bases that are related to wind and water erosion, and to infer hydrological functions, biotic integrity and soil stability. It is also a science-based monitoring protocol that can be easily used by local communities without assistance (Riginos & Herrick 2010), which makes it very useful in land assessment as in the "Farmers Heal the Land" project. Another observation to be tested by further studies is that the stick method seems to provide more economical use of time than does the modified Braun-Blanquet.

5. CONCLUSION AND RECOMMENDATION

The main purpose of land management assessment and monitoring is to provide indicators that can reliably assess the condition of the land. This study intended to compare and contrast the stick and modified Braun-Blanquet monitoring protocols. The investigation showed that the two assessing protocols provide the same tendencies. The estimate indicators can be related to the three attributes of ecosystems that include soil stability, hydrological functions and biotic integrity, and the indicators of rangeland health. The information from the two protocols could be extrapolated to a large area using remote sensing and GIS tools. The results can also be integrated in conceptual models such as S & T models to identify management trends and thresholds for control of land management. This study revealed the robustness of the two protocols to assess and monitor land management. Compared to the modified Braun-Blanquet, the stick method seemed to estimate greater cover of vascular plants, mosses, litter and rocks. The two protocols provided similar estimates of lichen and sedge cover. Nevertheless, the stick method may better assess land condition and monitor revegetated lands because it also provides supplementary indicators like plant base and basal and canopy gaps that are not identified by the modified Braun-Blanquet protocol. This study is preliminary and it therefore is not possible to recommend one protocol over the other. We recommend further studies which can supply more data to provide powerful statistical analysis. Future studies should include different types of land use and the time it takes to do the measurements, as it is important to know if the stick method really means economical use of time, carried out for the purpose of the Icelandic "Farmers Heal the Land" project.

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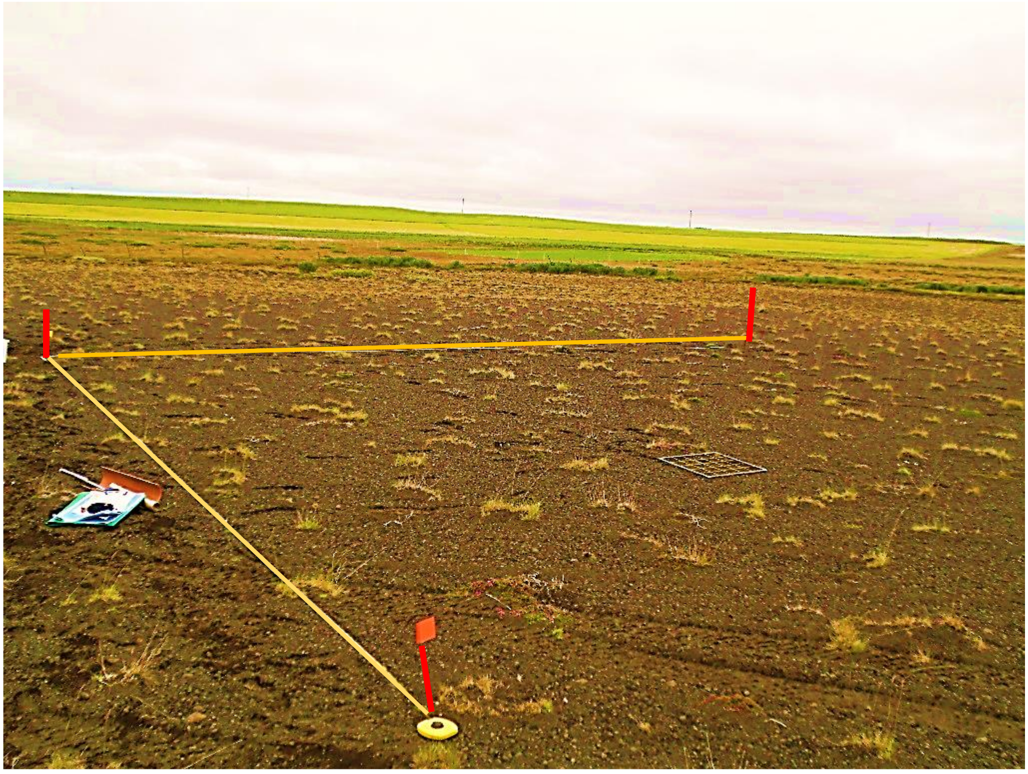
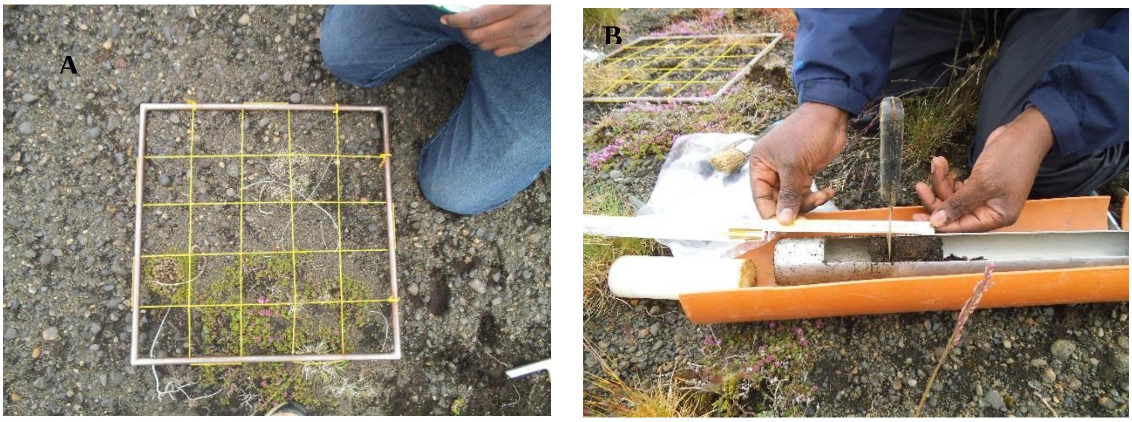
APPENDICES



Appendix 1. Location of one of 0.25 m² quadrat in the 10 m ×10 m plot. (Photo: I. Soumana, 9 July 2013).



Appendix 2. Photos showing (A) foliar cover measurements in 0.25 m² quadrat and (B) soil sampling with the auger to the depth of 5 cm. (Photos: I. Soumana, 9-12 July 2013).

Background Datasheet - Version 2

Basic Site Information

(Record only first time site is visited. Used for interpretation.)

Site name: ____________________

Description of where the site is located:

Description of central point location:

GPS

Datum: ____________

Northing: ____________

Easting: ____________

Vegetation Type:

	None:	Few:	Many:	Dense:
Shrubs	○	○	○	○
Trees	○	○	○	○

Common Species

Grass: ____________

Shrub: ____________

Tree: ____________

Forb/Herb: ____________

Soil Surface: 0 - 10 cm

Texture:	Colour:	Colour:
○ Sticky	○ Red	○ Light
○ Slippery	○ Grey	○ Medium
○ Sandy	○ Brown	○ Dark

Sub-Surface: 10 - 30 cm Compared to soil surface:

More:	Less:	Same:		
○	○	○	Sticky	○ Lighter
○	○	○	Slippery	○ Same as
○	○	○	Sandy	○ Darker

Sub-Surface: 30 - 50 cm Compared to 10 - 30 cm:

More:	Less:	Same:		
○	○	○	Sticky	○ Lighter
○	○	○	Slippery	○ Same as
○	○	○	Sandy	○ Darker

Soil Depth: ________ cm

Slope

Length of string: ______ m

% Slope: ____________

(% Slope = [1 / (2*length)] * 100)

Shape:
(walking down the longest slope)

Shape:
(walking across the longest slope)

Observational Indicators

(Record each time data are collected)

Season: ____________ Date: ____________

- Indicators of Change -

Signs of Erosion:

	None:	Few:	Some:	A lot:
Rills	○	○	○	○
Gullies	○	○	○	○
Litter Dams	○	○	○	○
Pedestals	○	○	○	○
Soil Deposition	○	○	○	○
Water Flow Patterns	○	○	○	○
Sheet Erosion	○	○	○	○
Other: __________	○	○	○	○

Soil Surface Hardness:

Soil surface (0 - 10 cm) in large gaps (gaps > 1 stick) is:

○ Hard ○ Soft ○ No large gaps

Soil surface (0 - 10 cm) in grassy areas is:

○ Much softer than
○ Softer than
○ The same as

the soil surface in large gaps.

- Indicators of Site Use -

Grass (not protected by shrubs/trees) has been grazed:

○ Not at all
○ Lightly
○ Moderately
○ Heavily

Species that have done most of the grazing: ____________

Trees/shrubs have been browsed:

○ Not at all
○ Lightly
○ Moderately
○ Heavily

Species that have done most of the browsing: ____________

Recent cutting:

○ Grass cutting
○ Tree cutting

Animals visible while at site?

○ No
○ Yes Species: ____________

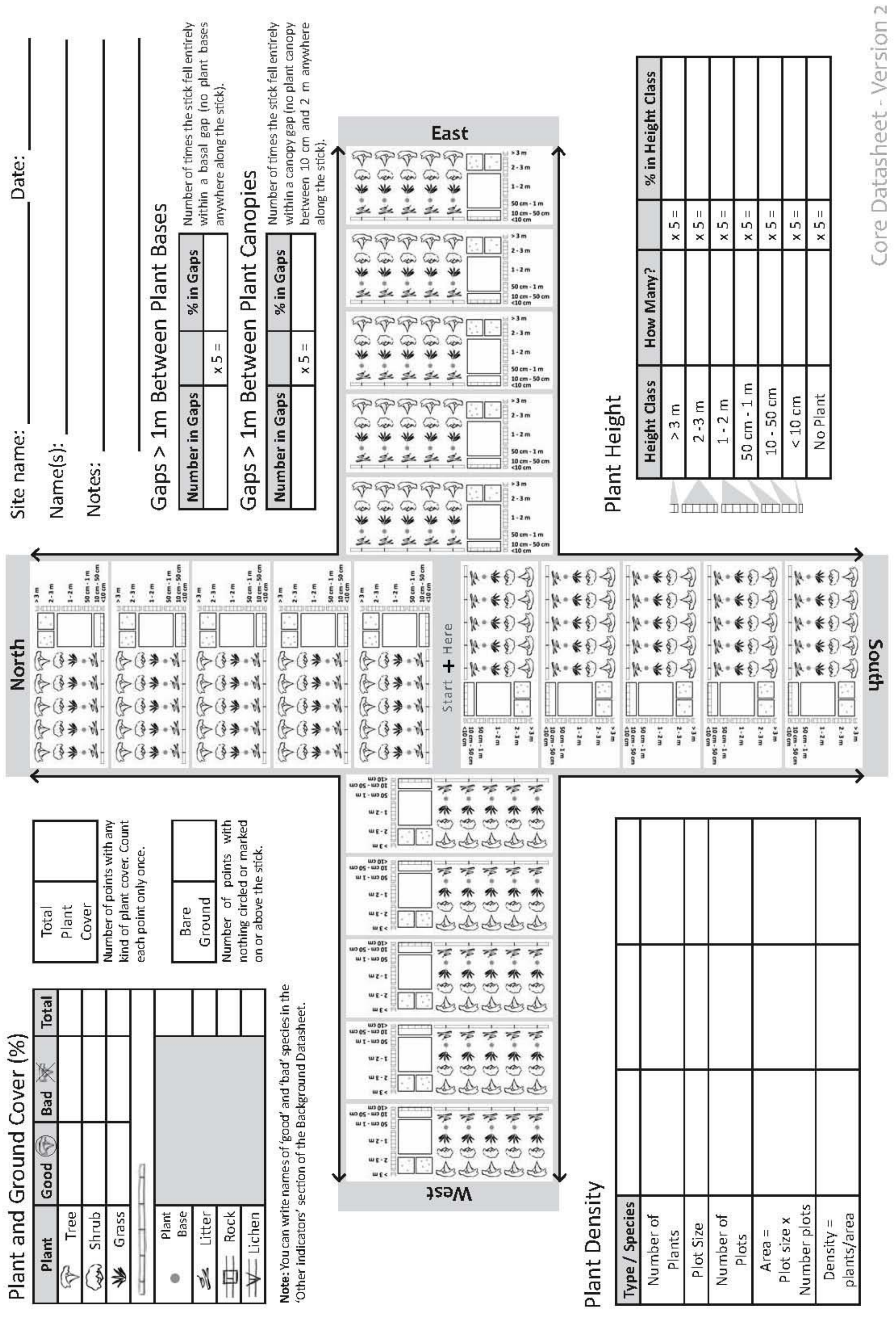
Distance to water:

Temporary	Permanent	
○	○	<200 m
○	○	200 m - 1 km
○	○	1 - 3 km
○	○	>3 km

Distance to boma / settlement:

Used within the past year	Used more than a year ago	
○	○	<200 m
○	○	200 m - 1 km
○	○	1 - 3 km
○	○	>3 km

Other indicators, notes, & observations about the site:



Appendix 3. Sheets to record data using the stick method (Riginos & Herrick 2010). The sheets were modified in this study; the original sheets constituted tree, shrub, grass, lichen, plant base, litter, and rock, whereas the modified stick method had moss, forb, shrub, grass, lichen, plant base, litter and rock.