**Title:**

**OK TITLE IMPORTANT – we do NOT want to just say meta in drylands because that will open up opportunity for editors to say – not general enough. I think the framing of active versus passive restoration is VERY general and novel and we used drylands to show you need to compare these two categories of restoration. Active versus passive restoration is APPLICABLE to everyone in all systems – we show that is the case here using drylands.**

So my vote is

Active versus passive in title

Restoration

Drylands – sure

And if possible a bit catchy. Many options listed here but ones that have these elements are my preference.

**Getting something for nothing: a synthesis of active versus passive restoration in drylands globally.**

A global meta-analysis of restoration in dryland ecosystems. – weak…

A global synthesis of active versus passive restoration methods in drylands.

70 characters…

just thinking we can push out the title a bit and use those characters to sell the paper even more – my fav titles are the ones that highlight the main finding as well…

Active restoration in drylands more effective than passive restoration.

Restoration of ag-lands: a synthesis of active versus passive restoration in drylands globally.

**Money for nothing and your restoration for free: a synthesis of active versus passive restoration in drylands globally. Meet too! 102 characters – need to reduce**

**Money for nothing and your restoration for free: a synthesis of active versus passive restoration in drylands globally.**

Or

**Getting something for nothing: a synthesis of active versus passive restoration in drylands globally.**

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**Abstract:**

Dryland ecosystems, including those found in Mediterranean regions worldwide, are global biodiversity hotspots. Agricultural intensification and land degradation continue to pose a serious threat to biodiversity in these regions, which is likely to only intensify with global population growth. However, water scarcity has led to opportunities to re-claim degraded agricultural lands for habitat for plant and animal species. Restoration of former agricultural lands can be expensive and time intensive, and results can be variable based on the types of restoration practices implemented. To increase the efficiency and overall effectiveness of restoration practices in dryland agricultural systems globally, we conducted a meta-analysis, focused on determining the most common and successful restoration practices. Overall, we found that active restoration practices for soils, vegetation, and wildlife lead to the most positive outcomes, and have the lowest overall variances, versus passive restoration practices. This was especially true for soil restoration, which saw negative results overall for passive restoration approaches. Armed with this information, restoration practitioners can focus limited resources on those practices that are likely to provide the greatest positive impact.

**One Sentence Summary:**

A contrast of active and passive restoration methods in dryland ecosystems highlights the critical need for the adoption of active techniques to ensure positive ecological outcomes for soils, vegetation, and wildlife.

Ie the framing I prefer if you like? Basically do throughout paper – ie deserts are the case study.

Active restoration practices in dryland ecosystems led to the largest most positive outcomes for soils, vegetation, and wildlife.

**Main Text:**

TOPIC sentence should be restoration – again – you prefer the big picture I propose – FLIP story

Restoration is crucial in all ecosystems globally. We need to know what interventions generate consistent and positive outcomes that support enhanced ecosystem function and services. Drylands include natural (i.e. semi-arid grasslands, shrublands and deserts) and managed ecosystems (e.g. farmlands), are some of the most extensive and biodiversity-rich systems on Earth. They cover over 40% of the global land surface (*1*) and account for XX% of the global agricultural acreage (insert relevant citation). Drylands provide key ecosystem services, such as food provision (crops and livestock), carbon sequestration, biodiversity support and land for renewable energy development (*1*–*3*). Dryland ecosystems are also some of the systems most threatened by land conversion (e.g. to agriculture), land degradation, and climate change. (*6*), all of which threaten the delivery of ecosystem services (*7*). While increased land protection (e.g. conservation easements) (*8*) and better land management practices (*9*) could benefit remaining habitat in drylands, changing conditions in general and water scarcity in particular have created an opportunity to re-claim and restore degraded dryland agricultural lands for plants and wildlife (*10, 11*). In order to seize this opportunity to restore dryland habitat, practitioners need clear guidance on which restoration practices will have the greatest positive outcomes given limited resources.

Restoration practices can be characterized as active or passive (i.e. natural recovery), which differ in the total amount of resources invested (e.g. time, money and human assistance) (*13*). The impact of individual restoration practices on soils, vegetation, and wildlife often takes many years to evaluate (*14*). Given the diversity of restoration practices that have been implemented and assessed in dryland ecosystems globally (*14*, *15*), it is crucial to evaluate their overall effectiveness to guide future restoration opportunities (11).

To evaluate restoration practices and outcomes in dryland ecosystems globally, we performed a meta-analysis of 66 peer-reviewed publications (*16*, *17*) from 19 different countries (Fig. 1). We focused on restoration practices and outcomes within agricultural lands, which included both farmland (i.e. crops) and grazing/natural land (Fig. S1). We classified each restoration practice and outcome as either active, which involves human assistance in the restoration process, or passive, which allows for natural recovery of the system (*18*). We assessed the success of each restoration practice and outcome using the log response ratio (lrr) (*19*).

We grouped active restoration practices into three categories based on their focus: soil, vegetation, and water addition (Table 1; Table S1), and passive restoration practices in to three categories, soil, vegetation, and grazing exclusion. We evaluated active restoration outcomes across four categories: soil, plants, animals, and habitat (Table 1). The habitat category was used to represent outcomes for integrated measures of plants and soil. We evaluated passive restoration outcomes across the same three categories: soils, plants, and habitat (Table 1). We used random effects models to account for the variability within the studies evaluated (*17*), and then applied meta-regressions to test the potential influence of two additional covariates, aridity (*20*) and the time scale of experiments (*21*), on restoration outcomes.

We found that active restoration led to more positive outcomes (lrr estimate = 0.22, 95% CI= 0.21 to 0.23) than passive ones (lrr estimate= -0.34, 95% CI= -0.37 to -0.31). All three types of active restoration practices had net positive outcomes (Table 1). Passive soil recovery overall had net negative outcomes (Table 1A, Fig. 2). Passive vegetation recovery and grazing exclusion overall had positive effects on restoration outcomes (Table 1A, Fig. 2). Aridity and time since restoration practice implementation both significantly influenced the effectiveness of active restoration practices (lrr estimatearidity= -0.01, 95% CI= -0.02 to -0.01; lrr estimatedexp.time= 0.003, 95% CI= 0.003 to 0.0035), while for passive practices only time since implementation was significant (lrr estimatedexp.time= 0.01, 95% CI= 0.008 to 0.01). Effectiveness of active restoration practices overall decreased with increasing aridity. Within the active restoration outcomes evaluated, we found that active restoration was positive overall for soils, plants and habitat, but negative for animals (Table 1B). We found that soils cannot restore passively, but that plants and habitat can (Table 1B). We found that water addition was the most effective restoration practice, followed by soil and plant restoration practices (Table 1A).

Overall, we found that active restoration is often required to see positive outcomes in dryland ecosystems, which differs from a recent meta-analysis in tropical forests that found passive natural succession is the most effective strategy (*22*). These differences are likely driven by rainfall, soil fertility and vegetation productivity which are severely constrained in dryland ecosystems (*1*). We also focused on agricultural crop lands, which may be require more active restoration practices to overcome past soil disturbances, nutrient inputs, and pesticide use

(*24*).

Resources are and will always be limiting for restoration, especially in developing countries (*1*). Our meta-analysis reveals that there while you may be able to get something for nothing from restoration in dryland ecosystems (Table 1), active restoration practices lead to more consistently positive outcomes for soils, plants, animals, and overall habitat values (Table 1) so may be worth the increased investment in time and money.

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**Data and materials availability:** Include a note explaining any restrictions on materials, such as materials transfer agreements. Note accession numbers to any data relating to the paper and deposited in a public database; include a brief description of the data set or model with the number. If all data are in the paper and supplementary materials include the sentence “All data is available in the main text or the supplementary materials.” All data, code, and materials used in the analysis must be available in some form to any researcher for purposes of reproducing or extending the analysis.

Supplementary Materials:

**Materials and Methods**

Literature search and eligible criteria

To conduct this meta-analysis, we followed the PRISMA guidelines (Preferred Reporting Items for Systematic reviews and Meta-Analyses; Fig. S2) (*26*). To identify different restoration practices implemented in drylands globally and to compare the effectiveness of active and passive types of restoration practices and outcomes, we systematically searched in the databases Scopus and Web of Science using the following term combinations: [restoration\* desert\* vegetation\*] OR [restoration\* grassland\* desert\*] OR [restoration desert\* plant\*] OR [restoration "agricultural lands"] OR ["restoration techniques" desert\*] OR ["passive restoration" desert\* plant\*] OR ["active restoration" desert\* plant\*] OR [revegetation abandoned desert\*] OR [restoration "agricult\*land\*" desert\* plant\*] OR [restoration dryland\* vegetation] OR [restoration semiarid\* plant\*] OR [restoration arid\* plant\*]. The searches were conducted in September 2018 and returned 1504 published articles.

We collected data from studies that met the following inclusion criteria: (1) research articles including results, no review articles; (2) agriculture as the main disturbance reported (crop lands and grazing lands); (3) studies with treatment (restoration practice) and control (no intervention) groups; (3) reported statistical analysis and significance of treatments. After the application of the above inclusion criteria, a total of 66 studies were included in the meta-analysis (Fig. S4).

Data extraction

We extracted data of the restoration practice implemented in each study and classified them as active or passive restoration. As a high variety of restoration techniques were implemented globally, we grouped different practices that addressed a similar restoration goal into four main categories: soil, i.e. including those practices with soil intervention; vegetation; water addition and grazing exclusion. “Soil” and “vegetation” practices included both active and passive types of restoration, while “water addition” was classified as an active restoration practice and “grazing exclusion” as a passive restoration practice. Moreover, for each study we extracted data of the restoration outcome adopted to measure the effect of the restoration practice (*17*). We grouped the different outcomes into four general groups as well: soil, plants, animals and habitat. These four outcomes groups were measured by studies with an active restoration approach, while passive restoration studies have not evaluated the “animals” group .

We collected data of all the response variables reported in each article. For each response variable, we extracted data of mean, standard deviation and *p*-value. When these data were showed in figures, we used WebPlotDigitizer (*27*) to extract them. In addition, we collected data of the mean annual temperature and annual precipitation from the study sites of each article to calculate the aridity index (*20*) and, of the length of experiments expressed in months. The aridity index and the time scale of experiments were used as covariates in statistical models (see below).

Statistical analysis

**Table 1.** Start this caption with a short description of your table. Format tables using the Word Table commands and structures. Do not create tables using spaces or tab characters.

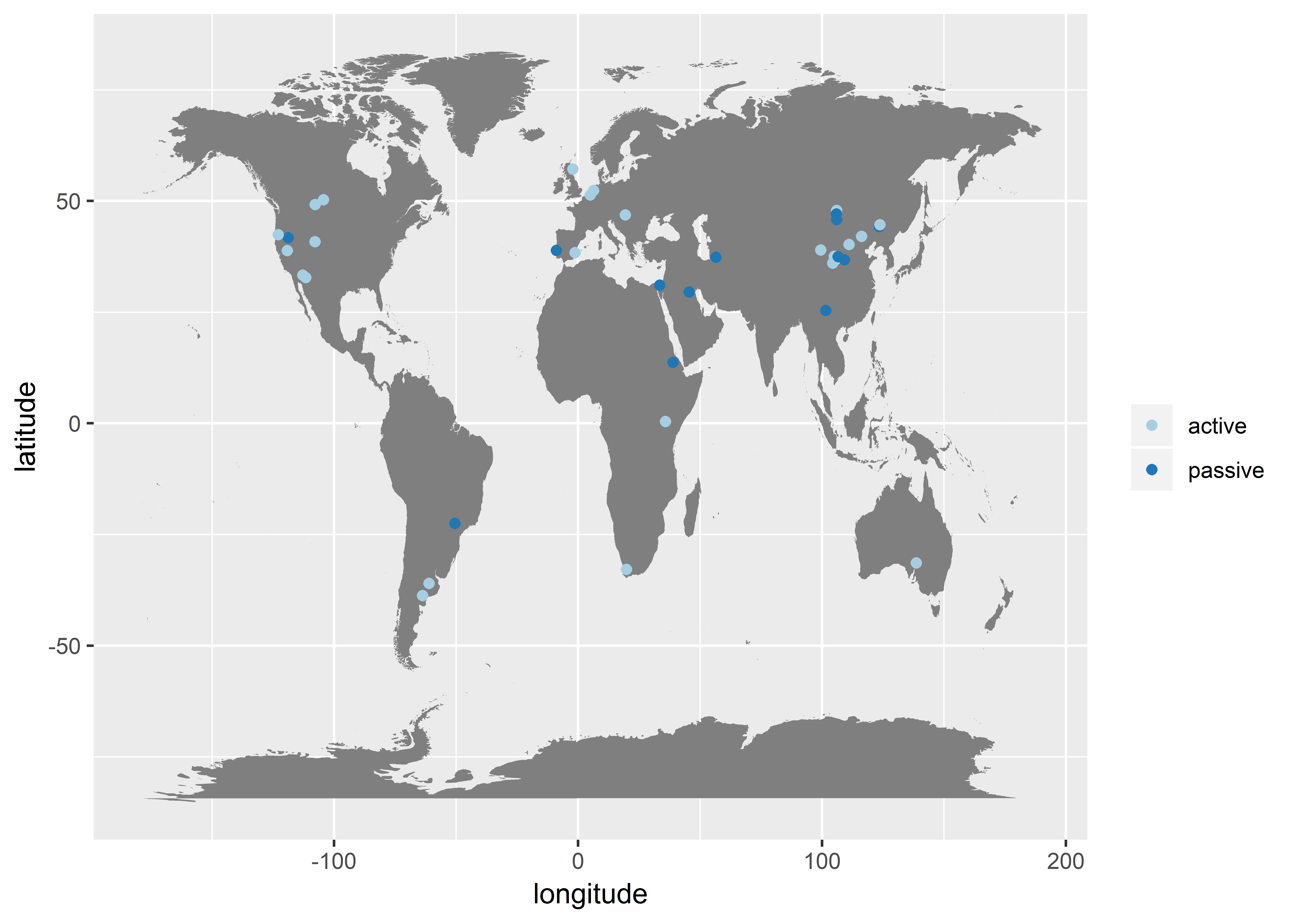
|  |  |  |
| --- | --- | --- |
| **Restoration** | **Log response ratio estimate** | **95% CI** |
| *(A)* | | |
| Active restoration practices | | |
| Soil | 0.31 | [0.30, 0.33] |
| Vegetation | 0.18 | [0.17, 0.20] |
| Water addition | 0.64 | [0.55, 0.73] |
| Passive restoration practices | | |
| Soil | -0.76 | [-0.82, -0.70] |
| Vegetation | 0.26 | [0.21, 0.32] |
| Grazing exclusion | 0.13 | [0.03, 0.24] |
| *(B)* | | |
| Active restoration outcomes | | |
| Soil | 0.22 | [0.15, 0.28] |
| Plants | 0.51 | [0.49, 0.52] |
| Habitat | 0.06 | [0.04, 0.08] |
| Animals | -0.11 | [-0.12, -0.11] |
| Passive restoration outcomes | | |
| Soil | -0.76 | [-0.82, -0.70] |
| Plants | 0.44 | [0.03, 0.85] |
| Habitat | 0.16 | [0.1, 0.22] |

Figures S1-S2

Table S1

References (1-31)

**Fig. 1.**



**Fig. 2.**

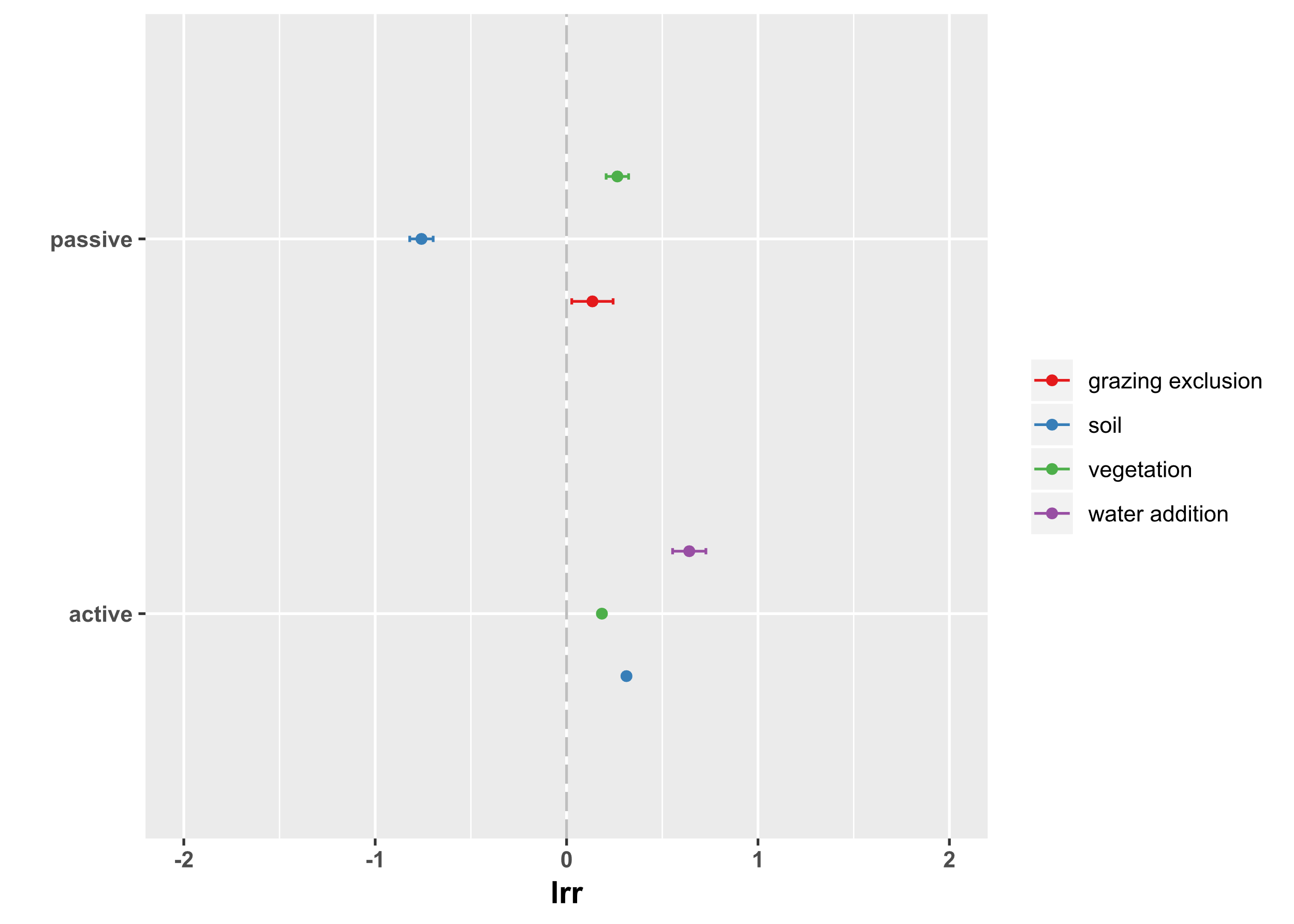


Fig. S1

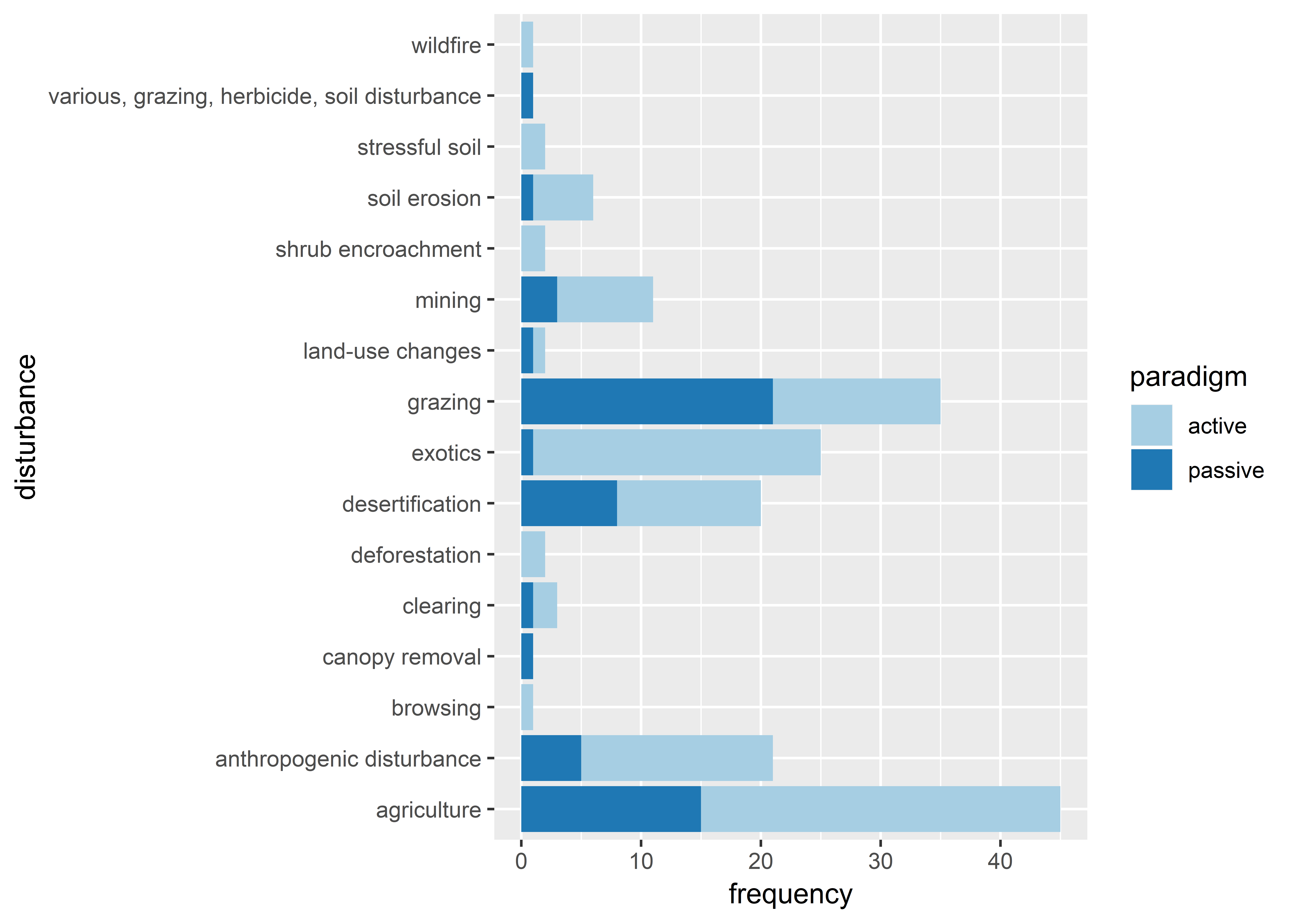


Fig. S2 PRISMA report

Table S1 list of different restoration practices and the categories made to group them ??