We thank the referee #2 for his/her critical comments and suggestions on the assumptions of the applied methodology, the implications for ecosystem rehabilitation, and for finding critical typos in the manuscript.

General comments

Comment: It is not clear what is meant by “design” in the context of ecosystems restoration. It needs to be defined with clear criteria. How will the drought assessment alter the rehabilitation measures for a post-mining landscape? I suggest that the title of the paper should reflect this by eliminating the term “design drought” and by introducing the term “risk assessment” or “risk framework”, or alternatively, rework the paper to quantitatively define the design issue and within this context the term “design drought” Either way, I suggest the title and contextual focus to be changed accordingly.

Response: Similar to the concept of Intensity-Frequency-Duration (IFD) design rainfall, which aims to quantify the recurrence interval if rainfall events based on their intensity and duration, we apply the same concept to quantify the recurrence intervals of periods of water deficit (droughts) based on their severity and duration, and refer to this concept as Severity-Duration-Frequency (SDF) design drought. While IFD design rainfalls are a well-established tool in civil engineering and hydrology to assess the risk of infrastructure failure (e.g., buildings, bridges, water damns, flood levee), we believe SDF design drought could be used in a similar way to assess the risk of ecosystem rehabilitation failure due to droughts.

We see how “design drought” in the title can be confusing as it needs to be defined first in the text, and therefore changed the title to “Severity-Duration-Frequency curves of droughts: An early risk assessment and planning tool for ecosystem establishment in post-mining landscapes”.

We have also added extra text describing how the method proposed in this paper could be used in the context of ecosystems restoration in accordance with the other referee’s comment on the lack of information describing implications for ecosystem rehabilitation. The new section that we have added is section 4.3. This includes table 3:

4.3 Application of design droughts to rehabilitation planning

Table 3. Management actions for addressing specific kinds of drought characteristics identified with SDF curves for the southern hemisphere.

Management domain	Management actions	Type of drought
Plant species selection	Drought tolerant species	LS, LP, SP, SS
	Quickly germinating species	SS
	Species with physical/chemical dormancy	LS, LP
	Shade tolerant species on southern aspects	LS, LP
	Light tolerant species on northern aspects	LS, LP, SP, SS
	Annual grasses	SS, SP
	Perennial grasses	LS, LP, SP, SS

	Trees	LS, LP
Planting/seeding regime	Trees require repeated establishment	LS, LP
	Annual/perennial grasses are successful after rain events	SS, SP
Soil characteristics	Deep top soil	LS, LP, SP
	Amendments of silt/clay	LS, LP
	Gentle slopes	LS, LP
	Mulching	SS
Irrigation method	Regular irrigation	LS, LP
	Seasonal irrigation	SS, SP
	Critical stage irrigation	LS,LP,SP,SS
	Drainage system	LS, LP

SS – High recurrence of short time scale (3 month) severe droughts
SP – High recurrence of short time scale (3 month) prolonged droughts
LS – High recurrence of long time scale (12 months) severe droughts
LP – High recurrence of long time scale (12 months) prolonged droughts

One of the major outcomes of this study is to support land managers and/or rehab practitioners to make fundamental decisions on appropriate management actions in the context of drought frequency. For rehabilitation to be successful in the face of severe and prolonged droughts, there are a range of management domains and management actions that need to be considered in response to recurrence intervals, drought severity, and drought duration (Table 3). These management actions can be categorized into four domains: plant species selection; planting/seeding regime; soil characteristics; and irrigation method.

Selection of suitable plant species based on drought type is one of the key management actions for successful rehabilitation. Some management actions can be applied to all drought types (Table 3: LS, LP, SS, SP). These include planting drought resistance species (*Acacia* spp., *Banksia* spp., *Casuarina* spp.); planting drought tolerant species in northern aspects to address drier conditions that result from higher solar radiation causing increased evaporation (Sternberg and Shoshany, 2001); and planting perennial grasses (*Eragrostis* spp., *Themeda* spp. (Bolger et al., 2005)) which may not be affected by long-term water deficits. In locations which have long-term (12 month time scale) droughts with high recurrence of severe and prolonged water deficits (Table 3: LS, LP), such as Mt Isa and Quilpie, over seeding with seeds that have physical/chemical dormancy may increase the probability of germination during favourable time periods (Hilhorst, 1995; Arnold et al., 2014). Additionally, planting drought intolerant species in southern aspects may increase their survival (Sternberg and Shoshany, 2001). However, these species need to be shade tolerant as southern aspects get less solar radiation in winter. Locations with short-term droughts with high recurrence of severe but not prolonged droughts, with rainfall throughout the year (Table 3: SS), such as

Wagga Wagga can be planted with annual grasses and seeded by seeds with short germination periods.

Soil characteristics play a critical role in plant available water and a number of strategies may need to be employed to make soil more favourable to plant establishment. Except for mulching, all of the management actions within the soil characteristics management domain can be applied to locations with high recurrence of long-term severe and prolonged droughts (Table 3: LS, LP), such as Quilpie and Mt Isa. For locations with high recurrence of short-term prolonged droughts (Table 3: SP) (e.g. Melbourne), increasing the depth of topsoil can increase water holding capacity (Audet et al., 2013; Bot and Benites, 2005). Similarly, by mixing silt and clay soil in the topsoil and reducing slope gradients may facilitate infiltration and increase soil water retention capacity (Audet et al., 2013). For tropical locations with high recurrence of short-term (3 month time scale) severe and prolonged droughts (Table 3: SS, SP), such as Cairns and Weipa, ground cover such as mulch and planting fast growing cover (e.g. Buffel grass) may reduce evaporation and maintain soil moisture to allow for the establishment of drought sensitive slower growing species (Blum, 1996).

Utilising irrigation methods for specific site characteristics is a cost effective strategy for any rehabilitation plan. Regular irrigation with proper drainage systems that distributes water is an effective strategy in locations with high recurrence of long-term severe and prolonged droughts (Table 3: LP, LS). For locations with high recurrence of short-term, severe and prolonged droughts (Table 3: SS, SP), with seasonal rainfall (e.g. Brisbane, Sydney, Kingaroy, Brigalow), seasonal irrigation and irrigation at critical stages of plant growth (Blum, 1996), such as germination, and root or pod development periods is a more efficient way to ensure plant survival throughout drought spells.

Comment: Paper will have a wider readership if the description of the methodology includes a clear statement of the assumption made as well as a clear statement of its limitations.

Response: We elaborated possible limitations of our study in section 4.3 (now 4.4) “Future research”. Regarding the assumptions made to estimate the SDF curves, we added the following paragraph to the beginning of the methodology (section 2):

“Estimating SDF curves involves some uncertainties associated with the length of the observed rainfall data, the applied drought index, the probability distribution functions used to fit the observed severity and duration, and the estimated copula parameter (Hu, Liang et al. 2014). To overcome these uncertainties we tested the applicability of drought indices for locations in different climatic regions by calculating the correlation of three selected drought indices. Likewise we used the best fitted probability distribution functions and copula for each site (Fig. 2).”

Detailed Comments

Abstract

Comment: 4810/4 is water the stressor or the lack of water, Clarify

Response: Thanks for pointing this out. Of course the lack of water is the primary abiotic stressor for (agro)ecosystems across eastern Australia we altered the text in the following way “For some of the agro-climatic regions in Eastern Australia lack of water is the primary abiotic stressor..”

Comment: 4810/17 not clear why evaporation plays a minor role

Response: Here we refer to the tropical locations (Weipa and Cairns), where rainfall is equal or exceeds annual evaporation and therefore evaporation does not critically affect the output of the drought indices RDI and SPEI.

Comment: 4810/24 vague statement, specific mentioning of what those “environmental barriers” are?

Response: We agree and added “[…] site-specific environmental barriers such as *flood and drought events*”

Introduction

Comment: 4811/18 …The relevance water stress during rehabilitation is reviewed here. Can this be resolved in more detailed perhaps in the discussion section such that quantitative criteria could be derived?

Response: In the revised manuscript, and in accordance with the other referee’s comments, this is addressed in section 4.3 and table 3.

Materials and Methods

Comment: 4816/22-24 Notation of eq. 1 not clear. Shouldn’t it be… for I_i < 0 without the negative sign and the absolute value within the summation?

Response: That’s correct, thanks for pointing that out. Equation 1 should read as:

$$\boldsymbol{S} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{D}} |-\boldsymbol{I_i}|$$

Comment: 4818/15-20 Table 3 doesn’t exist.

Response: Thank you for catching this; we used the wrong table numbers. We revised the references to table 3 accordingly.

Comment: 4819/2 Fig. 7 is mentioned before Fig. 5 and 6. Correct sequence.

Response: We revised the figure numbers accordingly.

Implication

1. 4822/26-28 Good example of vague statement: Why can't you be specific and provide an example with mentioning the species, the duration values and then use your method to make a well-informed assessment of the risk of rehabilitation failure. If we don't have that type of information available, than the method proposed is useless.

   Response: As described above we addressed this in the new section 4.3 of the revised manuscript.

2. 4823/16-29 This section is a good example of the use of the indices. The issue of simplification and the use of surrogate information should be presented earlier in the paper to justify why you go through the statistical analysis of correlating your different indices.

   Response: We added two sentences to the introduction (4812/18). "In many parts of the world evaporation data are unavailable or incomplete and simple rainfall indices are most commonly used. In this study we compare indices incorporating evaporation (SPEI and RDI) with the simple rainfall index SPI in order to determine the accuracy of using SPI across different climatic regions."

Future

3. 4824/23-26 The statement that the analysis in not predictive should be presented earlier in the paper (introduction). As mentioned above, list all assumption of the method (for example assumption on independence etc.) before you introduce the method and then clearly indicated limitations based on that.

   Response: In the revised manuscript, we moved the statement to the introduction.

   "While uncertainty is associated with any step in figure 2, a detailed uncertainty analysis is beyond the scope of this study. Yet, given that we have applied more than one probability density function and copula to fit the observed severity and duration, we believe uncertainty is minimised to an acceptable level. We are confident that further research, as outlined in section 4.3 of the old manuscript, can address these uncertainties."

References

Hu, Y.-M., Z.-M. Liang, Y.-W. Liu, J. Wang, L. Yao and Y. Ning (2014). "Uncertainty analysis of SPI calculation and drought assessment based on the application of Bootstrap." International Journal of Climatology: n/a-n/a.