Review Paper

New approaches: Use of assisted natural succession in revegetation of inhabited arid drylands as alternative to large-scale afforestation

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Abstract
It is a great concept to let nature do the work of revegetation, however in semi-arid and arid regions the process of natural succession, if it occurs at all, typically requires many years of undisturbed development until an increase in biomass becomes measurable, hence it rather is applied to remote, sparsely populated regions and may be underrated as a measure to restore native vegetation, particularly in inhabited arid areas. What are the factors that make arid successional processes successful, how to expedite, and how to enable their use for the ecological revegetation of densely populated drylands? We review restoration methods that combine the planting of shelterbelt compartments with successional revegetation of the internal area, protected from wind and drought. Various measures of assisted natural succession can be applied to greatly accelerate the revegetation, including soil tillage, amendment with organic matter and the inoculation with cyanobacteria or lichens to form biocrusts. The aim is to initiate the development of native, water-saving savanna with biodiversity, resilience and adaptability to climate change. A narrow twin shelterbelt module could facilitate the use of natural succession within inhabited and peri-urban areas, also serving as protective greenbelt for cities. A pilot is planned in a peri-urban area of Northern Iraq, with a successional area of 125–150 m between shelterbelts. Land-use of agriculture, gardening and recreation can be integrated within the successional area, which also generates engagement of residents in the maintenance work. Planting of shelterbelts is required on 10–25% (not 100%) of the restoration area, therefore the use of assisted succession within protective compartments is expected to have both, ecological and economic advantages over large-scale afforestation.

Keywords Arid revegetation · Inhabited drylands · Shelterbelt compartments · Climate adaptability · Assisted succession · Restoration measures

1 Introduction

Large arid and semi-arid desert bordering regions: Are they inherently vegetation-less? Arable land is constantly being lost due to desertification processes, hence the increase in vegetation cover is an important measure in reducing the causative forces of erosion from water and wind [1]. Large-scale tree plantations in drylands of Northern China had an estimated overall survival rate of only 15% [2]. We have learned that density and choice of plants should match local soils, ecological situation and climate. The use of non-native trees with high water requirement, too dense planting in combination with spells of drought will bear risk of hydro-ecological

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stress; planted "forests" may outgrow the available water resource even decades after plantation [2, 3]. The rather low number of tree species planted in the initial campaigns in Northern China often resulted in poorly adjusted vegetation prone to wide-spread damage from insects and plant diseases, with a need to replant these areas with trees and shrubs of better ecological fit [4, 5]. Ecological restoration models that generate climatically adaptable vegetation are therefore urgently needed. They could help to further develop protective vegetation cover in regions with degraded soil, to stabilize and regain land that is suitable for agriculture, and finally, their use in geo-engineering projects could support the large-scale carbon sequestration in desert-border regions.

Other examples of arid and hyper-arid tree plantations are the greenbelts used in North Africa to protect urban areas from dust, sand storms and heat. The greenbelt in Niamey, Niger (2500 ha) includes a recreational park, the greenbelt in Nouakchott, Mauritania protects the city and outskirts from the extremes of the Saharan climate. It has taken over 30 years to cultivate these larger arid greenbelts, which would demonstrate the urgent need for more efficient greening methods [6].

Restoration of drylands will achieve high survival rates when the resulting vegetation is ecologically well suited to local conditions with comparatively high diversity, as is gained best by the processes of natural succession [7]. However, the more hostile the environment in terms of soil quality and aridity, the more time is required (decades or even hundreds of years) and the less convincing the results found for succession in comparison to active planting, as shown for the revegetation of sand dunes [8]. Harsh climatic and geological conditions may not allow for any natural succession at all to occur [9]. As an example, depositional areas at the base of hills are likely to resist any restoration efforts because of a sequence of erosion problems related to landscape scale. Other causes of strong successional disruption can involve geomorphology, herbivory, or nutrient cycling [10]. Such results may have led to a situation in which the value of successional processes in revegetation of arid drylands is underrated. How can successional processes be used more effectively in the revegetation of drylands? In principle, any method that facilitates the growth of plants in arid climate should also help to initiate and expedite these processes [7]. We review recent measures which are hoped to potentially make succession successful here. These include methods that were demonstrated to be successful in the restoration of soil for long-term agricultural use e.g., [11, 12].

The need for many years of development [9] may have limited the use of natural succession in the revegetation of drylands to sparsely inhabited remote regions where there is protection over many years from further disturbance e.g., by nomadic herds [3]. Do we have to limit the use of this important process to remote and non-populated regions, and what kind of restoration measures could be used to achieve an expedited successional revegetation? A method for revegetation of drylands that combines the active planting of twin greenbelts and the process of sheltered natural succession was suggested [13]. Besides this model of planted "renaturation compartments" and a similar shelterbelt system used in Northern China [3], we review methods of soil tillage, soil amendment [12] and the formation of "biocrusts" within only one year, done by inoculation of the surface soil with cyanobacteria, mosses or lichens [14–17] to identify how these methods can be applied, also in combination, in order to initiate and accelerate successional processes.

Vegetation developing in succession is expected to have great advantages over planted or non-native trees, particularly under rapid climate change [18]. Can successional processes play a major role in the large-scale revegetation of (degraded) arid areas? Restoration projects need to address important questions of getting the buy-in from residents and their support in managing and maintaining the revegetated area locally, over many years [19]. We review the deliberate reversal of desertification through combined methods of natural succession and active planting, to be applied in particular to inhabited arid and semi-arid drylands. How can these revegetation concepts meet the land use interests of the local communities, such as recreation and gardening? Some "success factors" of assisted succession in drylands will be identified, together with the logical work order of combining these methods in a restoration project. The feasibility and hydro-ecological considerations are hoped to further develop sustainable restoration techniques for arid drylands.

2 Non assisted successional revegetation of drylands in northern China

Successional processes take many decades, particularly in drylands. Restoration methods can direct and expedite them, as will be described below (**3.-5.**). Active restoration includes techniques such as the introduction of species and improvement of soil moisture and organic matter [7]. In Northern China, the application of successional processes as a measure of large-scale revegetation of drylands is a rather new approach [3]. Here, a "successional restoration" concept was suggested by McVicar et al. [20] in which hill-slopes with 15° or greater are left to natural succession so that any vegetation pattern was allowed to develop in this area. The main advantage of making the best possible use of successional processes is the comparatively high diversity of the resulting native vegetation, showing high climate adaptability after being introduced in this way [1]. A disadvantage is a need for many years of undisturbed development of the vegetation in strictly protected areas. In China, a process called "natural reforestation" was initiated in remote semi-arid and arid areas around 2006, and more than a decade later, the increase in biomass on these lands became measurable through remote sensing methods [21]. According to the authors, they are the first to report the successful use of natural succession in Northern China drylands. The results were compared with those from revegetation plots where active planting had been started at around the same time as the "natural reforestation". Not surprisingly, an increase in biomass here became measurable soon after plantation. This fast increase in biomass clearly is an advantage of the active tree planting method. However, the overall survival rate achieved with planting of trees in Northern China since 1949 was estimated at 15%, and the high mortality rate was attributed mainly to the selection of not adapted tree species, dense planting and related hydro-ecological stress [2].

3 Soil organic matter as important component in revegetation

The soil organic carbon content and soil organic matter (SOM) are important components in soil fertility and plant growth hence these are important factors in restoration projects to control desertification. The process of SOM mineralization contributes to nutrient supply, however, in agricultural experiments assessing crop yield, the growth of plants and SOM content were not directly correlated. Rather, it was suggested that the biochemical composition and turnover rates are the soil parameters crucial for the crop yields achieved [22]. Sandy soils with a low water holding capacity were shown to limit the development of vegetation during long drought events [23]. Particularly in arid context, the water holding capacity is an important soil parameter related to SOM, and experiments to amend the soil with organic matter (such as straw or wood) have shown to increase soil fertility and the amount of water available to plants [24–27]. Water storage capacity was increased by 50% when sandy soil was amended with wood chips (5%) and covered with branches. Nutrients from decomposition of the wood chips were found to increase the biomass production over at least five years compared to controls [12]. The method was therefore suggested as long-term treatment to restore degraded soils, and its suggested use in combination with other restoration measures is reviewed in below (**6.1)**. As a related observation from semi-arid restoration practice (Northern Spain): Coalmine tailings are difficult to revegetate due to their pedological constraints. In a comparison of numerous examples, a resilient pioneer vegetation with native shrubs developed more than 25 years earlier in those restoration areas where surface soil (with top layer removed) had been added]23}.

Due to the reduced soil compaction certain amount of SOM will ease the infiltration of water [26]. During years of drought, soils with high organic content were shown to be more productive which was explained with an approximately 100% increase in water capture and retention, measured during rainy periods [11]. The important activity of soil biota and decomposing microorganisms depends on the existence of SOM. This interaction can improve soil characteristics such as aggregation and aeration, particularly in the plant rhizosphere [27, 28]. SOM, moisture, aggregation and texture of soil also affect the soil characteristics of penetration resistance: High resistance values can impact root elongation, access to water and nutrient uptake of plants [29].

In summary, soil fertility is based on a minimum SOM and the interaction of soil biota (bacteria, fungi, other destruents) and abiotic particles with the plant roots. These findings indicate that the soil and SOM will play an important role in plant growth as well as in any restoration project that is based on natural succession.

4 Planting of woody compartments for windbreak to assist successional processes

In a model region of Northern Jiangsu, China, the dense planting of shelterbelts has been successful in enabling productive agriculture on formerly degraded land with only 3% vegetation cover and windy, hot semiarid climate [30]. Wang et al. [3] suspect that there are hydro-ecological limitations to tree planting done in "naturally treeless" drylands and they suggest to differentiate the restoration methods in accordance with local climatic condition: A mix of trees and shrubs on 25% of the area in semi-arid climate, a reduced woody coverage of 15% in arid and only 10% coverage in hyper-arid climate. They report that such "quasinatural" method is being applied to the drylands in Northern China in establishing woody shelterbelts, with grasses and shrubs growing on the remaining area. These shelterbelt systems would help in the sand fixation [3]. It is likely, though not expressively mentioned, that the windbreak caused by these systems

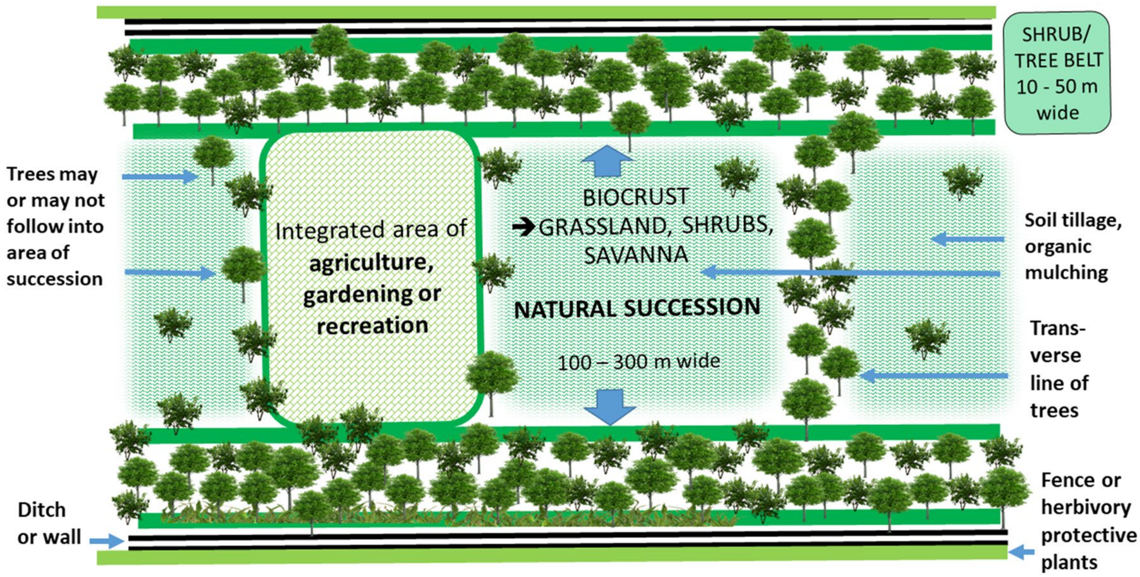

Fig. 1 Restoration module: Two flanking greenbelts with area of natural succession between them. Depending on local situation, areas of various land use are integrated. In this kind of model, numerous measures of assisted natural succession can be combined: Protection from wind (windbreak) and dust, increase in relative humidity, tillage and amendment of soil, inoculation with biocrusts

has been supportive in processes of natural succession and the revegetation of the remaining areas between shelterbelts.

Our restoration module suggests the planting of shelterbelts at similar coverage as in the above method to form protective compartments, in combination with protected natural succession to occur on the areas inside and on the outer belt sides. The concept is to create networks with increased levels of relative humidity (RH) and soil moisture content (SMC) that hydrologically connect isolated vegetation patches of a region [13]. A further enhanced model is depicted in Fig. 1. Two greenbelts, 10–50 m wide depending on local conditions and possibilities, are planted in parallel to form compartments between them where native savanna can develop in natural succession, partially protected from wind, drought and sand. Savanna developing here will have a proportion of woody plants in accordance with local mean annual precipitation (MAP) [31]. Based on studies of windbreak [32] the twin belts are close enough to each other to form a two-sided windbreak with a compartmental microclimate of increased RH and SMC. Installation of straw mats until the belts have reached certain density/ height or the planting of transverse lines of trees (Fig. 1) could provide additional protection; ditches or walls are constructed outside to collect rainwater. An example of the twin greenbelt model to be piloted in the Iraq will be presented in **6.2** to give more detail around the construction and possible selection of plants for such restoration module.

5 Biocrusts and other success factors of succession in drylands

A technique developed to restore disturbed desert surfaces that may also improve the growth conditions for pioneering vascular plants is the inoculation of surface soil with cyanobacteria, lichens or mosses, resulting in the formation of biocrusts. These have been shown to reduce erodibility and increase SMC and soil nutrients [14–16]. Biocrust propagules can accelerate the development of crusts which otherwise may take decades. Surfaces incubated with cyanobacteria were 80% covered with protective biocrusts within a year in temperate deserts, thereby SMC and soil structure improved within rather short time [17]. Pond culture or bioreactor cultivation of cyanobacteria has enabled the treatment of areas sized up to three hectares [33, 34]. A supposedly water-saving method uses broadcasting of biocrust fragments [35]. Low level of moss was established within two years in rather cool sites by broadcasting of moss material [36].

Disturbed desert soil can be amended with nutrients and organic mulching to expedite the development of biological and chemical characteristics of undisturbed soil, the rebuilding of the original soil structure however will take time [7]. Soil tillage, harrowing or ploughing can be important measures in case of compacted soil, typically caused by concentrated grazing, leading to reduced water infiltration, surface erosion and the exacerbation of drought effects [37]. Harrowing, mulching and amending of soil with stabilizer and organic matter will increase soil fertility and water retention [22] and the important development of mycorrhizal fungi [38]. Mycorrhizal colonization also was found to be higher in organic crop production using compost amendment in comparison to conventionally farmed soil e.g., [39]. Existing plants are maintained for their nursing effects [40]. Plants can be seeded, with seed collected from adjacent undisturbed biotope or similar environment [7].

Shrubs are important during the early stages of natural succession due to their various ecological services: They reduce the run off and deliver food, nutrients and shade [41]. The shrub layer with leguminous pioneer species may be regarded as an indicator of natural succession in restoration: An age dependent gradient was observed on topsoiled mining sites, from early pioneer species to oldest communities with certain portion of woody plants [42]. In deserts, canopies of trees and shrubs create islands of increased nutrient levels and local conditions that enable the germination of seeds from the local seed bank [43]. Planting of hydro-ecologically well-adjusted shrubs and trees as in the following combination model (**6.**) would make use of this nursing effect by introducing native plants of late-stage savanna.

6 Combining methods of assisted natural succession within planted twin greenbelts

6.1 Work order to combine measures of assisted succession

The obvious success factors of natural succession in drylands reviewed in **3.–5.** may be combined and applied to maximise acceleration of the process. The protected environment of greenbelt compartments is expected to accelerate the successional process [44]. In order to achieve optimal assisted succession in drylands, a combination of the various reviewed methods is suggested which could be done in the following practical order:

(1) Soil tillage (harrowing, ploughing)—module areas where soil is compacted [22, 37]
(2) organic matter (e.g., compost, wood chips, branches, straw) worked into soil, mulching of cover soil [12]
(3) planting of shelterbelts [3] or twin greenbelts [13] for optimal windbreak, using native shrubs and trees, fences, ditches, water pools
(4) creating maintenance paths, particularly in areas of assisted succession where initial irrigation is planned
(5) depending on local seed bed optional dispersal of native plant seed transplanted from adjacent donor biotope [7]
(6) inoculation with cyanobacteria, mosses or biocrust fragments [15, 17, 35] on most disturbed parts of the successional area
(7) biocrust development will require regular irrigation during first months
(8) in semi-arid areas of MAP > 300 mm, the belt trees are watered during planting and would typically not require further irrigation [6].

At the end of the first year biocrusts may have developed already, contributing to soil moisture [17]. The young trees and shrubs of the planted shelterbelts start to grow; fences and/ or additional straw mats contribute to protection from wind and animals. After one or two years, the first plant seeds in the successional area may have germinated, producing patches of seasonal vegetation, seedlings of perennials may start their development. The mechanized treatment for large-scale restoration based on an integrated establishment of both, biocrusts and vascular plants is yet to be investigated further [36]. The two may represent communities of different successional stages, hence may not coexist over long time. Anyhow the effect of biocrust cover to increase the SMC [17] could locally support the germination and growth of vascular savanna plants.

Soil amendment with compost or wood will introduce SOM with water retention capacity, nutrients and the development of soil biota over the next years [24, 25]. Further growth of the shelterbelt plants, seedlings and biocrusts will introduce gradients of wind forces, shade, SMC and nutrients across the successional area.

6.2 Feasibility of assisted succession in peri-urban areas

So far, the use of succession in drylands is rather limited to rural regions [21]. Protected successional development of savanna inside greenbelt compartments would allow its use also in inhabited regions. A respective pilot model is planned in the Kurdistan region of Iraq near the city of Erbil, in collaboration with the Ministry of Agriculture. As in many semi-arid regions, drought and degradation have become socio-economic factors here [45, 46]. The following are some of the feasibility considerations, also in respect of the peri-urban location.

Examples of native species used in Iraqi Kurdistan afforestation are *Cedrus libani* and *Pinus brutia* (Ministry of Agriculture Erbil, unpublished) with an expected mature height of 10–12 m. The windbreak effect of trees has been studied with variable outcome e.g., [47]. A value recently found for reliable windbreak in Mediterranean climate is a 12.7-fold of tree height [32]. The assumed final height of 10–12 m will thus protect a successional area over a range of around 125–150 m, which should be the maximum distance maintained between the two belts. The shelterbelts are constructed with exterior rows made up of smaller trees and shrubs (*Olea, Pistacia, Jatropha*) to protect the interior rows of larger trees. The number of rows is adjusted to local conditions of wind and sand encroachment. Fences or herbivory protective shrubs (e.g., *Jatropha curcas)* on the outer sides (see Fig. 1**)** will protect the module from damage caused by wild animals and nomadic herds. A question important for peri-urban vegetation is that of monitoring and control of fire. In this regard, the narrow structure of the pilot is expected to ease the monitoring and extinction of wildfires and to reduce the risk of fire spread [44].

In arid and hyper-arid climates, the height of native trees and shrubs after years of growth typically is rather between 2 and 10 m. Consequently, here the wind-protected area for successional development of savannah, if calculated according to the above algorithm [32], will be between 25 and 125 m wide. Depending on location and climate, native species may be limited to those having leaves only during the rainy season (e.g., species of *Acacia, Commiphora, Euphorbia*), in contrast to the Mediterranean evergreen species in the semi-arid example above. Hence, rather dense planting of shrubs and the additional use of straw mats on the outer sides of the modules will help to protect young shelterbelt plantations.

6.3 Engagement of residents, land-use, maintenance

Protection and maintenance of new vegetation areas is required over a period of many years and a common question is, how to involve local residents in the long-term maintenance of revegetation projects [48]. In the combination model of twin greenbelts and assisted succession [13], clearly defined sections could be embedded for gardening, orchards, agriculture or recreation (park, playground, sports ground) within the successional areas of such vegetation network, schematically shown in Fig. 2. This way the needs and interests of local communities are incorporated which is often overlooked in restoration [48]. Residents would be motivated to engage in the maintenance required during the maturation years of the shelterbelt plants. In general, such buy-in and engagement is required over at least the first decade of restoration projects [19].

Active planting on 10–25% of the revegetation area in this model is combined with succession and other land use on 75–90% of it. The use of successional components therefore reduces the planting efforts that would be needed for large-scale afforestation of the same area: On

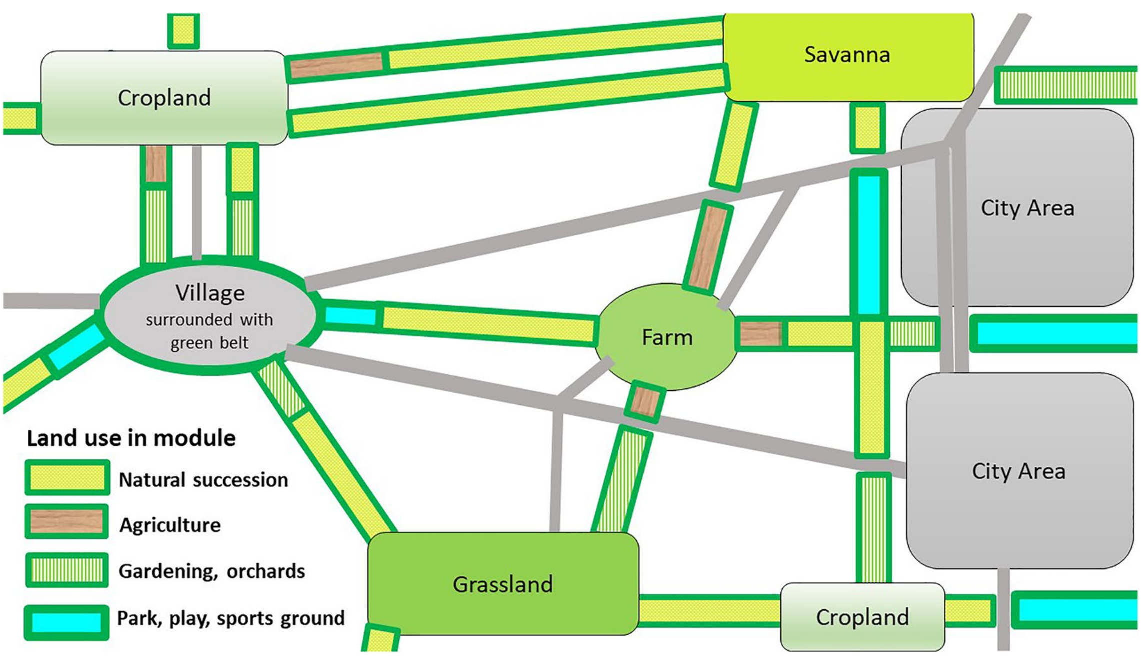

Fig. 2 Vegetation network and value creation for local communities. Twin belt modules close to city with sections for recreation or gardening, and modules in rural areas with sections of agriculture. The major portion of restoration sections is being revegetated by development of savannah in natural succession (light green modules)

a regional scale, the planting of shelterbelt compartments on 5% of a region would increase its vegetation cover by 20% or 30% once the succession has been successful. As an optimal solution for water-restricted regions, the handing over of the ultimate project responsibility to the local municipality was recommended [6].

6.4 Limitations of method, alternatives

The use of wind-protective greenbelts to assist the natural successional processes between them—this will be most effective in regions with constant wind or frequent storms. The combination of several restoration measures as outlined could have limitations in resources and restoration efforts. To keep the costs of nursery and plantation of saplings low the formation of greenbelts can be kept to a minimum number of plantation rows, flanked by wind protective fences. The raising of biocrusts will require additional work steps and irrigation, therefore its use could be limited to the open, more exposed central area of succession. Provision of large amounts of organic matter for soil enrichment or mulching of the successional area may be challenging. Any kind of biodegradable organic matter will be helpful [12], even in low amounts. Alternatively, the creation of only stripes or "islands" of organic matter would result in nutrient gradients, hence could promote diversification.

With all measures taken—tillage, soil amendment, mulching, biocrusts, wind protection, water collecting ditches, appropriate planting distances—ecologically well adapted shrubs and trees of the belts should not require irrigation following initial growth, even not in arid environments. However, in hyper-arid deserts a constant or seasonal irrigation may still be necessary over years or during extended spells of drought. Good results and high growth rates of *Eucalyptus* and other (non-native and native) tree species were found when using purified desalinated waste water for irrigation in hyper-arid conditions [49, 50]. The development of a water-efficient savanna vegetation on the larger successional area of the greenbelt model, when used in large-scale restoration, should improve the local hydrological situation and the need for irrigation of the native greenbelt plants may decline over time. Simulations of large-scale afforestation in hyper-arid deserts, based off tree plantations like the one evaluated in [50], have calculated that the large new vegetation cover will cause additional precipitation [51].

Irrigation of the successional area, however is not recommended, other than required temporarily for the development of biocrusts. A study of semi-arid restoration areas has evaluated the effects of irrigation and rather eutrophic soil amendment in which compost was given in addition to the application of topsoil. The vegetation promoting effects of these additional treatments faded out after more than ten years, even worse, the induced development of opportunistic plant communities seemed to halt further succession [52].

7 Discussion and conclusion

We have shown how models using shelterbelts and protective compartments in combination with other restoration measures related to soil and hydrology, and thoughtful combination of all these methods could enable and accelerate successional processes for their use in arid large-scale revegetation. Models like the twin greenbelt are suggested to create adapted native vegetation in an assisted, maybe expedited, ecological way instead of the cumbersome planting of large forestations with their known hydro-ecological challenges [2–5]. The large-scale use of natural succession in drylands has only recently been initiated in China, in regions where it is possible to close off remote areas for many years to avoid external impact, as in an example of remote reforestation in Inner Mongolia, China [3]. Models using closed and narrow shelterbelt constructions potentially can support successional processes and propagate their use in more densely inhabited semi-arid and arid regions.

The review of results from restoration and rehabilitation projects has revealed important parameters that can make natural succession successful in drylands, such as the development of mycorrhizal fungi: It is slow, but their communities are known to be important in the settlement of certain woody species and to increase soil stability, hence to reduce erodibility [53]. The suggested combination of restoration measures is likely to achieve synergistic effects: e.g., the amendment with organic matter (compost) and/or the mulching with woody material will also add soil microorganisms and seeds in support of the existing local seed bank, resulting in an expedited settlement of grasses, weeds, or shrubs. Another example of possible synergy is the development of biocrusts that was shown to be sensitive to strong wind [35], therefore, windbreak in the greenbelt compartments will support this early successional step, particularly in windy regions.

Natural succession leads to best suited and locally adapted vegetation created by nature, which in semi-arid and arid regions typically is a type of savanna. However, for numerous arid ecosystems the traditional concept of succession that leads into a stable and predictable state of vegetation following disturbance may not account as they could have various alternative stable-states, so that rehabilitation of degraded ecosystems in drylands would require management intervention and economic efforts [10], indicating the need to assist nature in its successional processes. Leaving desert bordering land unprotected over many years—this readily results in sand drifts and further desertification. Succession may even not occur at all on critical sites [9], therefore it may have been underestimated as a revegetation technique for arid environments.

The importance of windbreak will have to be evidenced in a comparison of the kinetics of greenbelt-protected against non-protected succession in drylands. According to current results from China the latter, i.e. succession in passive restoration in semi-arid climate will take at least 12 years until the increase in biomass becomes measurable [21]. The planting of greenbelt compartments in the suggested systematic way to provide nutrients and protection from wind, sand and disturbance between them to assist succession—this is a rather new model. The multitude of gradients (wind, temperature, light, RH, SMC, organic matter) achieved across the protected successional area potentially increases the diversity, hence the climate adaptability of the plant communities developing here [44]. The protection and combined methods of soil treatment should accelerate the successional processes, which indeed was already shown for the restoration of coalmine waste areas: Shrub vegetation developed within 15 years when topsoil (with higher content of organic matter and nutrients) was added to the restoration area, whereas comparable succession took more than 40 years without such treatment [23].

A disadvantage of restoration based on networks of narrow greenbelt compartments may be the widely extended and diverted structure of the restoration area, as it could be more difficult to control and maintain. Often the long-term maintenance of afforestation areas is not sufficiently planned [19]. Rather than closure of an entire area over long time (as done for unprotected succession), the assigning of portions of the greenbelt compartments to community´s land-use for recreation or horticulture (Fig. 2) could add value and keep up engagement in the important maintenance activities over many years. Such win–win situation would as well be solution to another dilemma criticized by Duguma et al. (2020): Most restoration interventions to-date had failed to engage the resident communities, these would not understand the benefits or incentives from such engagement [48]. In peri-urban context the twin greenbelt module can serve as a water-saving alternative to wide (single) greenbelts, providing much needed protection for cities in arid environments [6]. The city greenbelts in Northern Africa are so far planted only locally [6]. Rather narrow twin belt compartments could be an ecological and cost-effective solution to "connect the green spots" of arid peri-urban environments, as shown schematically in Fig. 2. The networking of peri-urban green areas in this way would make these more resilient to drought and extreme temperatures in future scenarios of climate change [54]. As an important feature in populated areas, the narrow construction can ease the control of fire spread.

The revegetation in protected and assisted successional mode as major part of the restoration area may get accelerated but could still take a number of years, however, with low water consumption, biodiversity and respective climatic adaptability and other ecosystem services being characteristics of the resulting native vegetation [1]. Naturally grown tree seedlings result in saplings that are more drought resilient than those raised in tree nurseries [55]. In comparison to large-scale afforestation, the typical African savanna has 10–30% of woody plant canopy, depending on MAP [31]. This fact seems to support the reviewed Chinese "quasinatural" approach [3], as well as the systematic use of assisted natural succession within compartments with low percentage of woody plants. Here, nature and local climate will define the final composition of the resulting vegetation cover, typically a savanna-like vegetation with low, only seasonal water consumption and greater drought resilience compared to large-scale afforestation. The suggested refined restoration model, if expanded into populated areas may offer possibilities to increase the quality of life of those living here. The efforts and costs of tree planting can be expected to be about 80% less compared to afforestation of the entire area.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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