Resilience of Post-Resource Landscapes

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Abstract:

This research investigates the resilience of post-resource landscapes with a focus on Broken Hill in NSW. Extraction practices have made these landscapes and the communities who live there vulnerable, and more so in the face of major disturbances such as land degradation, drought and water scarcity, loss of native vegetation cover, contamination of natural resources, climate change, political disturbance, and social disorganisation. Because individual responses to each social-ecological hazard are not adequate or within the scope of local infrastructure, broader resilience during everyday life becomes critical to effective adaptations in the face of evolving risks. Although rehabilitation of post-resource landscapes is typically considered independently of local communities, the research considers how a coupled system of social networks, inextricably interwoven with landscape renewal can strengthen the collective capacity of a city. This research undertakes a comparative analysis of two sites, Broken Hill in NSW, Australia, and Sarcheshmeh Copper city in Kerman Province, Iran, where mining activities have caused industry-related environmental pollution, a reduction in the capacity of the land, and an increase in the vulnerability of local communities. The research illustrates how the adaptation of existing infrastructures and the integration of regional interspecies logics that have proven their capacity to withstand and recover from hazards can offer a broader, regenerative ecological and social infrastructure, as well as a culture of knowledge and care for land. Developing collective capacities in this way can strengthen everyday activity, which makes both communities and landscapes more resilient while enhancing adaptation potentials to cope better with the sudden and unpredictable shocks.

Keywords:
Urban resilience, social-ecological system, everyday resilience, post-mining landscapes

1 Introduction

Landscape is an integration of ecosystems and society (Xu et al, 2021). While natural resource extraction contributes to the economic development aims of many countries, resource landscapes, due to long-term extraction practices, are less resilient and more vulnerable. Although rehabilitation of post-resource landscapes is mostly considered with respect to ecological networks, the broader concept of resilience thinking can improve opportunities to reassess the current situation, promote social cohesion, recombine sources of experience to develop knowledge, and actively identify new kinds of adaptability at multiple scales (Walker, 2004; Folke *et al*., 2010).

This research intends to investigate and stimulate interdisciplinary discussion concerning the social-ecological resilience of post-resource landscapes. Three key questions are raised to provide a systematic framework for enquiry to challenge thinking about the dual regeneration of degraded post-resource landscapes: How do extraction practices make landscapes and local communities who live there vulnerable?; Is the ecological response to post-resource-induced challenges adequate for recovery? and c) How can local communities adapt to changes and contribute to the recovery of degraded post-mining landscapes?

This research paper compares two post-resource desert landscapes— the city of Broken Hill in Australia and Sarcheshmeh Copper city in Iran — through the lens of resilience to understand how mining practices can create surprisingly similar environmental and social challenges. Applying an analytical research method focused on a 1930s landscape regeneration project in Broken Hill, it then considers how the development of ecological networks and local social networks in everyday urban life might enhance recovery from long-term extraction-induced degradation. It illustrates the importance of strengthening the capacities of post-resource landscapes, ecologies, and local communities simultaneously, so that they may better cope with sudden and unpredictable shocks.

2 Literature Review

2.1 Post-resource landscapes

All human communities critically depend on the natural environment. In recent years, the resource landscape has long been the focus of attention of environmental activists and researchers. The post-resource landscape is a common phenomenon of developed and developing countries. Post-resource landscapes are territories whose structural and functional characteristics, while directly and indirectly reshaped by past industrial practices, have not retained their industrial function.

Resource dependency refers to communities whose social order, livelihood, and stability are defined by the heavy reliance on limited natural resources and localised economies (Machlis *et al*., 1990). Post-resource communities face complicated challenges due to social, demographic, ecological, and economic decline. Resource dependency deleteriously impacts the environment through ecological alterations and biodiversity damage and can cause social and economic changes in local communities (Cashen, 2007, Shahid and Nabeshima, 2005). Resource-dependent communities experience broad social cleavages and ecological, economic, demographic, and structural changes after periods of economic growth, leading to long-term decline (Bluestone *et al.*, 2017).

Although natural resource extraction and related businesses improve employment and income opportunities in local and remote regions for a limited period, rapid market integration and degradation as a consequence of industrial activities can reduce resilience (Freudenburg, 1992). The financial benefits of resource extraction can accelerate growth in a short period of time but in the long term can depress economic growth and development in local communities (Hajad, 2021; Taguchi and Lar, 2016). Resource-dependent communities need innovative approaches to assist in their multi-phase transitions from resource-dependent settlements to sustainable urban systems (Campbell and Maclaren, 2021).

2.2 Resilience

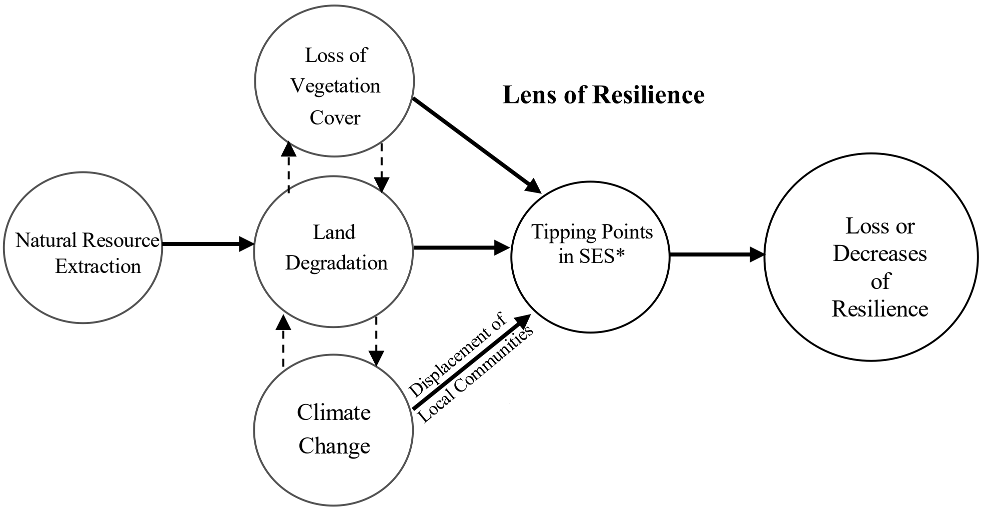
The landscape is a living system that interacts with ecological, social, cultural, and economic systems (Lu and Guozeng, 2022). Therefore, in order to promote landscape resilience, moving beyond a human scale and opening up multiscale approaches are essential (Kwak et al., 2021). The concept of landscape resilience focuses on a human-in-ecosystem perspective to understand the interactions between ecological and social systems and their dynamics (Kuldkepp, 2022; Berkes et al., 2003). Landscape resilience refers to the landscape's capacity to adapt (Mallick, 2021). Resilient landscapes can help to mitigate environmental and social hazards in urban environments and promote inclusive and sustainable growth. There are many definitions of resilience. From an ecological perspective, Holling (1973) defined resilience as the ability of the ecology to absorb disturbance and maintain the same relationships between populations and variables to persist through time (Holling, 1973). Tilman and Downing (1994) defined resilience as an ecological system's resistance and recovery ability to reach a single equilibrium point after a disruption (Tilman and Downing, 1994). Holling later expanded his approach to focus on the definition of a system and its capacity to adapt, suggesting that resilience was the capacity of a system to control behavior and absorb disturbance in order to maintain the same organisation, function, identity, and feedback (Holling and Gunderson, 2002; Walker, 2004).

Resilience has more recently been associated with urban environments: with the recovery, adaptation, and transformation of landscapes (Amirzadeh, et al, 2022); with the capacity of an urban system to allocate resources efficiently and to deliver essential services in the face of market perturbations and environmental shocks (Brock *et al.*, 2002; Perrings, 2006); and with the ability of regions to allocate resources productively and rebound from economic shocks without losing functionality (Hill *et al.*, 2008) Resilience is also a useful way of framing adaptive responses to natural disasters. Gunderson (2010) defines resilience as the capacity of coupled systems of humans and nature to deal with uncertainties and risks (Gunderson, 2010). Allan and Bryant (2011) focus on the potential of enhanced adaptive response and recovery in the event of disasters to enhance the quality of everyday urban life (Allan and Bryant, 2011). For Cutter et al. (2008), community resilience is the ability of the community to recover from hazards and cope with shocks in order to create adaptive responses based on the existing built environment and the interplay between social and spatial behaviour and natural processes (Cutter et al, 2008). Resilient landscapes are characterised by their capacity to adapt to a broad range of complex problems, across different aspects and scales (Kwak, et al, 2021) in a holistic and integrated way (Woodruff et al, 2021; Ribeiro & Gonçalves, 2019).

2.3. Post-mining resilience

Mining, by changing the nature of the landscape, clearing vegetation cover, and polluting the air, soil, and water can cause environmental contamination and land degradation (Moore, 2018; Krishnamurthy *et al*., 2020). Landscapes that have experienced extraction face a severe threat of land degradation and environmental challenges due to the decline in the capacity of land, loss of its biological, chemical, and economic productivity, and environmental degradation and climate change (Xie *et al*., 2020; Yang *et al*., 2018). Mezzadra and Adger (2000) investigated the relationship between social resilience and the ecological resilience of resource-dependent communities and found that resource endowment creates constraints on the social development of post- resource communities (Mezzadra & Adger, 2000). In such a situation, local people face climate change impacts and severe livelihood problems and are forced to flee their homes and find themselves displaced. (Carr 2018; Yang *et al*. 2018).

This research defines post-mining landscapes as weakened sites where mining activities have caused severe problems for both landscape and local communities. It looks at landscape as a complex Social-Ecological System (SES) regulated by dynamic interactions and feedback between community and nature. A system possesses a relatively stable state distinguished by its identity, function, and structure. When external stresses and shocks are incrementally threatening the state of the system, and the system cannot cope with external shocks, it reaches a tipping point, and after that, abruptly shifts from a stable state to a state of change (Saito *et al*., 2020).



* SES: Socio-ecological System

Figure 1. Interconnections between the main concepts of the research

While it is commonly assumed that increasing pervasive gradual pressure does not affect ecosystem functioning significantly, large and long-lasting pressures such as mining can force a socio-ecological system across a tipping point, which may eventually lead to its collapse (Cochard, 2017; Saito *et al*., 2020). Once a system crosses a tipping point, there are often severe impacts on ecological components, and loss of substantial and immediate ecological feedback can affect the social sustainability of the system. In most systems that have crossed a tipping point, the new state is characterised by uncertainty, with a high cost for a reversion back to its prior state (Yletyinen *et al*., 2019). Regarding the relationship between ecological and social networks, enhancing the social life of post-resource landscapes can affect a post-resource landscapes' capacities to recover.

3 Research Methodology

To develop a framework for resilience in post-resource landscapes, this research undertook a comparative analysis of two sites, Sarcheshmeh Copper city in Kerman Province, Iran and Broken Hill in NSW, Australia, where mining activities have caused industry-related environmental pollution, a reduction in the capacity of the land and an increase in the vulnerability of local communities. Documents, strategic and master plans of the cities of Broken Hill and Sarcheshmeh, historical documents, local newspapers, and related research projects were reviewed to identify the local communities' main ecological challenges and social problems. Focusing systematically on both post-mining case studies by using a social-ecological resilience lens and providing the event history analysis clarified how resilience can act as a useful frame to develop appropriate approaches to the rehabilitation of degraded post-resources landscapes.

4 Case Studies

4.1. First Case Study, Sarcheshmeh Copper city in Kerman Province, Iran

The Sarcheshmeh copper deposit is one of the world's largest Oligo-Miocene porphyry copper deposits. It is located in the central Iranian volcano-plutonic belt and 65 km southwest of Kerman Province, Iran (Atapour and Aftabi 2007). Exploration work and basic investigations of the mineralisation of ore deposits were carried out in 1967. Sarcheshmeh Copper city was planned and built according to the housing programs for personnel and engineers working in the Copper Complex in 1973, and it covers 534 acres (Ministry of Roads and Urban Development of Iran, 2013). During the mining boom, the mining industry impacted significantly on local communities, and more people looking for jobs were hired in the mining complex. At its peak in 1995, the number of people living in Sarcheshmeh increased by 9,070, the city council was established, and Sarcheshmeh was recorded as an independent city in Kerman Province.

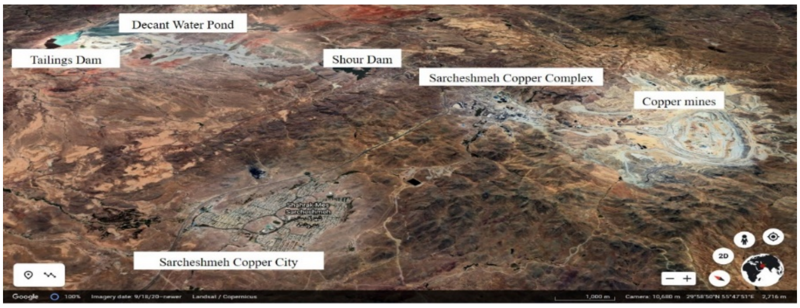


Figure 3. Locations of city of Sarcheshmeh copper, copper mine, and tailing dam, (Edit by Author, Source: https://earth.google.com/).

Figure 2. Loss of vegetation cover in Sarcheshmeh copper city between 2016 and 2021, (Source: https://earth.google.com/).

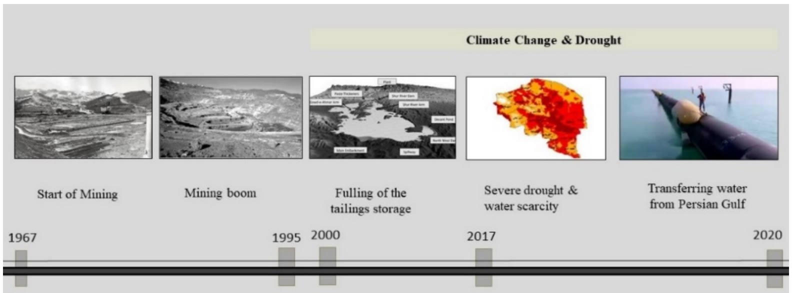


Figure 4. History timeline of Sarcheshmeh Copper City (Source of images: https://scico.ir/ & farsnews.ir/)

Due to intensive exploitation, technological advances in extraction techniques in other mining sites in the world, and competitiveness in global markets, the mining industry was caught in turmoil, and signs of a gradual decline began to emerge in 2005 (Ministry of Roads and Urban Development of Iran, 2013; Shamsaddin *et al.* 2020). One of the main challenges of Sarcheshmeh Copper city is drought and lack of access to water. A project for transferring water from the Persian Gulf to mine has been under implementation, with about 86% of the project developed since 2020 (Sazesazan, 2020). Comparing historical and recent aerial photographs indicates a loss of vegetation cover in the region between 2016 and 2021. Land degradation, climate change, and environmental problems caused by mining have had severe consequences on locals' livelihoods and social health. Internal migration data of Sarcheshmeh city indicates that because of ecological, social, health, and economic issues more than of 5 percent of residents are displaced annually (Ministry of Roads and Urban Development of Iran, 2013).

4.2. Second Case Study, Broken Hill in NSW, Australia

Broken Hill, located in the far west of outback New South Wales, is approximately 935 km northwest of Sydney, and 511 km from Adelaide (Broken Hill City Council, 2020). The Broken Hill Ore Deposit is one of the world's largest deposits of silver, zinc, and lead (Schatz, 2017). Founded in 1883, in response to the inter-regional effect of the mining boom in the late 19th century in Australia (Solomon, 1959), it was originally built as a temporary settlement to house mine workers and service the mining company (Solomon, 1959; Broken Hill City Council, 2020). During its mining boom period in 1952, flows of workers to this city exceeded 6,500 people, and the population of Broken Hill increased to 30,000 (Solomon, 1959; Broken Hill City Council, 2020). By the 1920s, due to a decrease in the price of minerals, mining activities were suspended in Broken Hill for several months, and finally in 1939 BHP, the first and the biggest mining company in Broken Hill, after exhausting the largest part of mineral deposit in Broken Hill estimated to be worth 180 million British pounds, closed its operations (Solomon, 1959; Broken Hill City Council, 2020). Since the 1970s, the town has experienced a long-term sustained decline due to deregulation of international markets, trade liberalisation, and gradual deterioration of resources (Fernández-Raga *et al.* 2017; Schatz, 2017; Battellino, 2010).

Figure 5. City of Broken Hill,1883, (Source: https://nla.gov.au/)

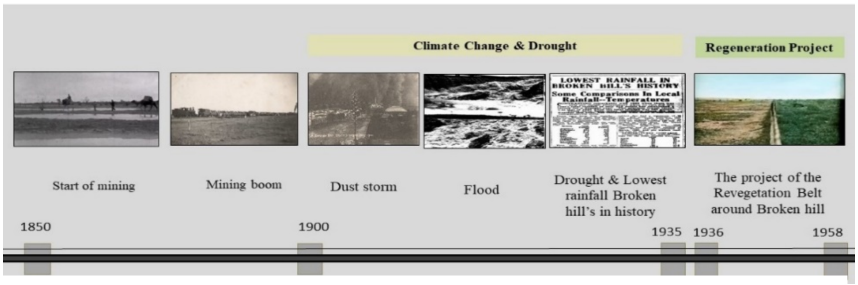


Figure 6. History timeline of Broken Hill,
(Source of images: https://nla.gov.au/& https://trove.nla.gov.au/)

A review and analysis of historical documents, local newspapers, and research about Broken Hill indicate that land degradation, soil erosion, dust storms, reduction in biodiversity, loss of native vegetation, water scarcity, and floods have been historically severe in this region. Roots of the abovementioned issues can be traced back to heavy overgrazing, foraging of commercial stock and rabbits, and timber felling for fuel and building construction in the region between 1900 and 1927 (Ardill, 2017; Jones, 2011). Mining activities also have exacerbated the situation, which has had negative impacts on the surrounding communities and environment at both local and regional scales (Entwistle *et al.*, 2019; Schatz, 2017).

Widespread destruction of flora and fauna and exposed fragile soils to wind caused dust storms, threatened the town's existence, and obliged Albert Morris, a resident of Broken Hill, self-taught botanist, and mining company senior assayer, to find fresh perspectives and come up with an innovative solution (Ardill, 2017; Jones, 2011). Morris witnessed the extinction crisis and turning of the landscape into a desert and took the view that establishing regeneration reserves could overcome the growing dust storms, soil erosion, and environmental problem which were threatening Broken Hill. Morris pursued his research in the local flora to regenerate the degraded landscape of Broken hill. He had the dream of creating a green belt around the city to minimise dust storms and sand-drift, protect native flora and fauna and improve the standard of living of local people (Ardill, 2017).

By 1936, Morris, with the co-operation of Margaret Morris (his wife), the Barrier Field Naturalists Club, mining corporations, and the government, initiated a regeneration project to restore ecological function by surrounding the city with a green belt of native vegetation (Ardill, 2017; Jones, 2011). Morris travelled to different regions in pursuit of botanical specimens. His project involved two major phases, including regeneration of the vegetation in a relatively quick

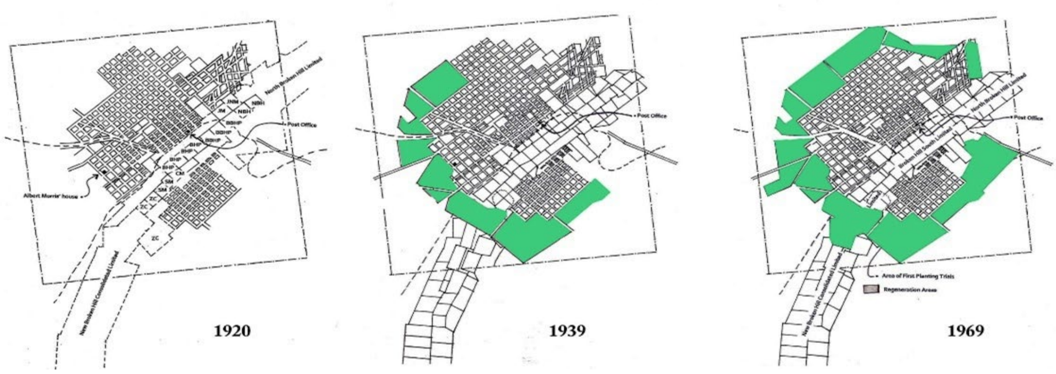


Figure 7. Project of Revegetation Belt around the Broken Hill, 1936 –1958, (Source: Jones, 2011).

timeframe and fencing of regeneration areas to enable natural regeneration of existing species and the restoration of native vegetation. Despite the limitation of resource material, he developed an expert knowledge of the local vegetation and provided seedlings of (*Eucalyptus*) gum trees and (*Atriplex nummularia*) old man saltbush, the disappeared local species, and native grasses for this project. This project is one of the first documented attempts in Australia to restore degraded landscapes using naturally occurring resources (Ardill, 2017).

Studies show that this project faced local communities' resistance to change. Local residents were heavily reliant on the enclosed common land around the town to collect their required firewood and keep their animals after the great financial depression; therefore, the aims of the project were not well received by some local communities at first (Volkofsky, 2017). Additionally, due to the project's connection to the mining corporation, there was some resistance. Within two years however, due to the reduction of dust storms in the region, the benefits of the reserve were clarified to local communities, and the concept was accepted and promoted by local groups (Volkofsky, 2017) and the Barrier Naturalists Club was established to maintain the green belt and does so to this day.

The applied approach to ecological regeneration, with its ongoing integration of community engagement promoted the social-ecological resilience of Broken Hill and can be considered a milestone in the history of the region.

5 Findings and Discussion

Analysis of two post-mining landscapes revealed some important relationships between ecological recovery, social resilience, community engagement, and everyday resilience. The following key finding suggest ways to enhance the resilience of post-resource landscapes.

First, the decline in post-mining landscapes not only leads to economic problems; it can also cause the loss of local community identity (Kim et al., 2020). Vulnerable landscapes and environmentally displaced people are the major victims of resource extraction practices. Severe environmental and economic impacts experienced by mining in post resource landscape encourage communities to leave, weakening both their social cohesion and social resilience. So, any regeneration plan for increasing resilience of the post-resource landscapes should include both ecological and social dimensions simultaneously.

Second, an event history analysis of post resource landscapes can clarify the complex factors that make post resource landscapes vulnerable, thereby suggesting where the most impactful rehabilitation work might occur. Projects that address multiple factors have the potential to become mutually reinforcing, with benefits that extend beyond a project's life.

Third, community engagement at the beginning of a rehabilitation project can help to clarify the needs of local people while also building a project's credibility. Community engagement is an essential part of long-term regeneration projects (Kim et al., 2020). It's worth noting that community engagement not only builds credibility and develops local supporters for the project but also can clarify the needs of local people as the major users in first steps of decision-making process, implementation and integration process, as well as project delivery.

Fourth, if a plan to rehabilitate post-resource landscapes does not receive attention at the right time, both social and ecological systems can experience exponential decline that is mostly irreversible, resulting in serious ecological issues in and beyond the region. This continued decline may pose a threat to the collective capacity of the post-resource landscape to regenerate and in particular, may weaken the identity and values of landscape and related local communities.

6 Conclusion

Although the application of ecological resilience concepts in regeneration of post-mining landscape is common, applying an approach incorporating social engagement and ecological recovery is rare. This research paper showed how mining-induced degradation could cause similar environmental problems in two very different post resource landscapes such as drought, soil erosion, land degradation, and contamination of natural resources, as well as severe social problems for local communities. However, this small case study review suggests that building trust with local communities in post resource landscapes may have significant implications. It improves community participation, encouraging local residents to collaborate on rehabilitation and environmental projects and in this way strengthens the robustness of everyday urban socio-ecological networks while enhancing the adaptive potential of vulnerable people and places to cope with sudden and unpredictable shocks.

Future research into the application of social-ecological resilience in the regeneration of the post-resource landscape is critical. Social-ecological resilience is a complex subject and involves many disciplines. This study covers the social, ecological and economic factors which contribute to post-resource landscape vulnerability of two case studies from a landscape perspective. Future research will be much more extensive, comparing the vulnerability of a number of post resource communities in Australia with similar histories ecological, social, cultural, and economic backgrounds to better understand how to improve a local communities post resource resilience.

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