Investigation into the Interconnected Nature of Environmental Problems and Identifying Keystone Environmental Problems

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Abstract

The study depicts the links between man-made environmental issues based on cause-and-effect relationships from real-world examples. For instance, man-made climate change is caused primarily by deforestation, draining of wetlands, intensive farming, and air pollution (greenhouse gas emission). Besides, every anthropogenic environmental problem may cause various other environmental problems, such as air pollution causes ocean acidification, ozone depletion, acid rain, disease, and visual pollution (smog). Similarly, deforestation causes biodiversity loss, land degradation, and human-animal conflict. About 255 links were examined among 40 identified environmental issues. In this web, certain causative environmental problems establish keystone links. Keystone environmental problems were identified from the concept map based on the criteria given by the following approach. When mitigating a man-made environmental problem, if it results in the permanent disappearance of one or more man-made environmental problems, then that mitigated problem can be considered a keystone environmental problem. To be specific, a complete dependency of the resulting environmental problem/s on the parent environmental problem has enabled the parent environmental problem to be considered a keystone environmental problem. This is because if the causative parent issue gets solved, then the resulting offspring/s cannot exist. Eight man-made environmental problems were found as keystones, such as air pollution, deforestation, population explosion, overexploitation of natural resources, global energy crisis, intensive farming, water pollution-water scarcity, and urbanization (industrialization)-urban sprawl-settlements.

Keywords: environment, environmental problems, manmade environmental problems, keystone environmental problems, interconnected environmental problems

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1. Introduction

The Gaia hypothesis first proposed by James Lovelock in 1969 stated "all living things on earth function as one super-organism that changes its environment to create conditions that best meet its needs". Also, it further justifies that all living things (the superorganism) poses the ability to self-regulate the system by successfully adapting to the changes or by overcoming the changes through their natural resilience. This cooperative not competitive process ascertains the continuity of life on this planet through evolution. However, man-made environmental problems severely affect this natural self-regulating and cooperative phenomenon. Man-made environmental problems are human-caused changes in the environment that alters the surrounding and makes it unfavorable for life's existence.

According to (Christensen, 1997) as cited in (Wahl, 2016a), in order to achieve a permanent solution to these problems, we need to travel beyond "sustaining innovation" and "disruptive innovation" and should effectively engage in transformative innovation. Wahl (Wahl, 2016b) stated that transformative innovation requires integrative whole-system thinking, and we can innovate win-win-win solutions and design for this systemic synergy. "To do so, we need to understand the interconnected nature of the converging crisis and respond with an integrative and participatory approach to this complexity". In this way, solutions can be created for the benefit of the entire biosphere and ecosystem. This study aimed to validate the following hypothesis: All man-made environmental problems are interconnected by cause-and-effect relationships, and ultimately it is possible to establish keystone environmental problems based on the dependency of linked environmental problems on them, a complete dependency of a resulting environmental problem on the parent environmental problem enabled the parent environmental problem to be considered as a keystone environmental problem. Thus, the study aimed to unravel the keystone environmental problems by analyzing the interconnection of environmental problems as cause-effect. In the recent past, several attempts were made to examine the clandestine characteristics of these interlinks by the US Environmental Protection Agency, some of them are given below.

Environmental systems are complex and interconnected (Committee on Research Opportunities and Priorities for EPA, Environmental challenges, 1997). Present humans are experiencing environmental problems that have not been experienced before in this century and they are manmade (Committee on Research Opportunities and Priorities for EPA, Environmental challenges, 1997). In 1986, the United States Environmental Protection Agency (USEPA) embarked on analyzing the risk caused by more than 30 environmental issues (USEPA, 1987; Vicky, et al., 2001) and subsequently, the United States National Research Council (USNRC) addressed on the same as risk characterization (Stern, Harvy, & Fineberg, 1996; USNRC, 1994; Vicky, et al., 2001). A "casual model" derived from (Hohenemser, Roger, & Robert, 1985) gives key characteristics of environmental problems such as persistence of the pollutant in the environment, population exposed, and health impacts. Vicky and co-authors (Vicky, et al., 2001) have also defined a sum of 18 specific descriptors to measure these characters.
In the UNEP (2012) report 21 issues were categorized based on the following criteria:
  i.   Issues that are critical to the global environment. Issues can be either positive or negative. But must be environmental in nature or environmentally related.
 ii.   Given priority over the next 1-3 years in the work programme of UNEP and/or other UN institutions and/or other international institutions concerned with the global environment.
iii.   Issues have a large spatial scale, and they should be continental, global, or 'universal' in nature (issues that occur in many parts of the world).

iv.   Issues that were recognized as 'emerging' based on newness, which can be the result of new scientific knowledge, new scales or accelerated rates of impacts, increased level of awareness, and/or new ways to respond to the issues.

[N.B. - Numbers given to the man-made environmental problems (E ##) in table 1 (below) are given in brackets in the following part of the literature and discussion.]

Table 1 : Environmental problems studied for interconnections

Overexploitation of Natural Resources	E1	Ocean Acidification	E13	Air pollution	E25	Human & Animal Conflict	E37
Vector-borne diseases	E2	Eutrophication	E14	Animal Slaughter & Cruelty	E26	Poverty-Disease-Disability-Inequality-War-Food insecurity	E38
Global Energy Crisis	E3	Groundwater contamination-depletion-salinization	E15	Climate change and Global warming	E27	Nuclear explosions-radiation-nuclear wastes	E39
El-Nino & La Nino	N4	Oil spills	E16	Deforestation-loss of grasslands- sea grass beds& mangroves	E28	Agrochemicals	E40
Biodiversity Loss	E5	Plastic pollution	E17	Coral destruction & bleach	E29	Population Explosion	E41
Wetlands or draining of wetlands	E6	Thermal Pollution	E18	Ozone depletion	E30	Invasive species or Exotic species	E42

Land degradation-sedimentation-soil erosion	E7	Solid waste	E19	Acid Rain	E31	Intensive farming	E43
Pollution through mining activities	E8	Heavy metal contamination	E20	Light Pollution	E32	Aquatic Weeds	E44
Establishment of Dams	E9	Pests or weeds	E21	Noise & Vibration pollution	E34		
Urbanization (industrialization)-urban sprawl-settlements	E10	Hazardous waste	E23	Impacts of biotechnology & Nanotechnology	E35		
Water Pollution & Water Scarcity	E12	E-Waste	E24	Visual Pollution	E36	*E11, E22 &E33 are not available (since the study originated as a board game, they represented the corners)*	

Man-made environmental problems are interconnected as cause and effect to one another. UNEP report gave 21 emerging environmental issues for the 21stcentury, which were ranked based on their linkages to the various dimensions of sustainable development. These issues cut across major global environmental themes such as food production, food insecurity (E 38), urbanization (E 10), biodiversity (E05), freshwater (E12), marine (E13, E16, E17, and E18), climate change (E27), energy (E03), technology and waste (E19). In addition, the report also concentrated on bridging the technology among countries, giving adequate funds or support to developing countries in order to combat the global environmental change and inclusive green economy. On the 25th of September 2015 at United Nations' sustainable development summit, the 2030 agenda for sustainable development was developed with the participation of world leaders from over 150 nations. The seventeen sustainable development goals are aiming to end poverty (E38), end hunger (E38), ascertain good health (E38) and well-being, quality education, gender equality, clean water (E12) and sanitation, and affordable and clean energy (E03), decent work and economic growth (E38) develop industry, innovation, and infrastructure, reduce inequalities, establishing sustainable cities (E10) and communities (E41), ensure responsible consumption and production (E01), climate change (E27) and disaster risk, protecting aquatic life (E05, E16, E17, E29, E06, and E18), protecting the life on land or secure the biodiversity (E05), democratic governance and peacebuilding and establishing global partnerships to achieve these goals (UNDP, 2018). Similarly, in the

recent 2012 GEO 5 report, issues such as heavy metal toxicity (E20), invasive or alien species (E42), and water scarcity (E12) such as groundwater depletion (E15) were classified along with other modern issues. Two dozen of reports were reviewed by the committee (Committee on Research Opportunities and Priorities for EPA, Improving Our Understanding of Environmental Issues, 1997), which included reports from the National Research Council, EPA's Science Advisory Board, technical societies, and research institutions.In addition , we also found that there is a need for the study on interconnections between environmental problems, as the research gap stated by Dr. Daniel Christian Wahl "we need to understand the interconnected nature of the converging crisis and respond with an integrative and participatory approach to this complexity" (Wahl, 2016a). Thus, this is the very first time, links between almost every man-made environmental problem (as cause-effect) were depicted in a concept map with the support of real word evidences, and the novel term keystone environmental problems was introduced with the definition established in this study.

2. Materials and Methods

The qualitative content analysis methodology was used. In reality, there must be separate research or empirical research to be done for each link in order to support the existence of the link between environmental problems quantitatively, but it is not practically possible to set up 255 empirical research works. Thus, the decision was made to bring supporting evidence from the previously published empirical studies. Thus, the study was carried out under the qualitative content analysis methodology with the consultation of Philip Adu (methodology expert from the Chicago school of methodology).

Major environmental problems were screened from published documents. And precisely 255 links were found in a hypothetical situation where human adaptability factors such as economic, social, political, health, genetics, evolution, and behavioural factors are absent (Mandal, 2010). To validate the hypothesis, the existence of all 255 links should be affirmed with the support of real-world examples collected from the reliable scientific literature. A concept diagram was created with the principles of the visualization tools of the Stockholm Environment Institute (SEI) of the United Nations Environment Management Group (EMG), which depicts a complete mental map of relationships among man-made environmental problems. Data collection was done until the data saturation has been achieved or when major categories show depth and variation. As an archival study, books, peer-reviewed journals, and papers from various sources including the internet were searched for relevant codes (links). The following diagram describes the functional flow of the qualitative content analysis methodology (figure 1). Finally, keystone environmental problems were identified from the concept map based on the criteria given by the following approach. When mitigating a man-made environmental problem (problem c), if it results in the permanent disappearance of one or more other (resulted) man-made environmental problems (problems d, e, and q), then that mitigated problem (problem c) can be considered as a keystone man-made environmental problem.
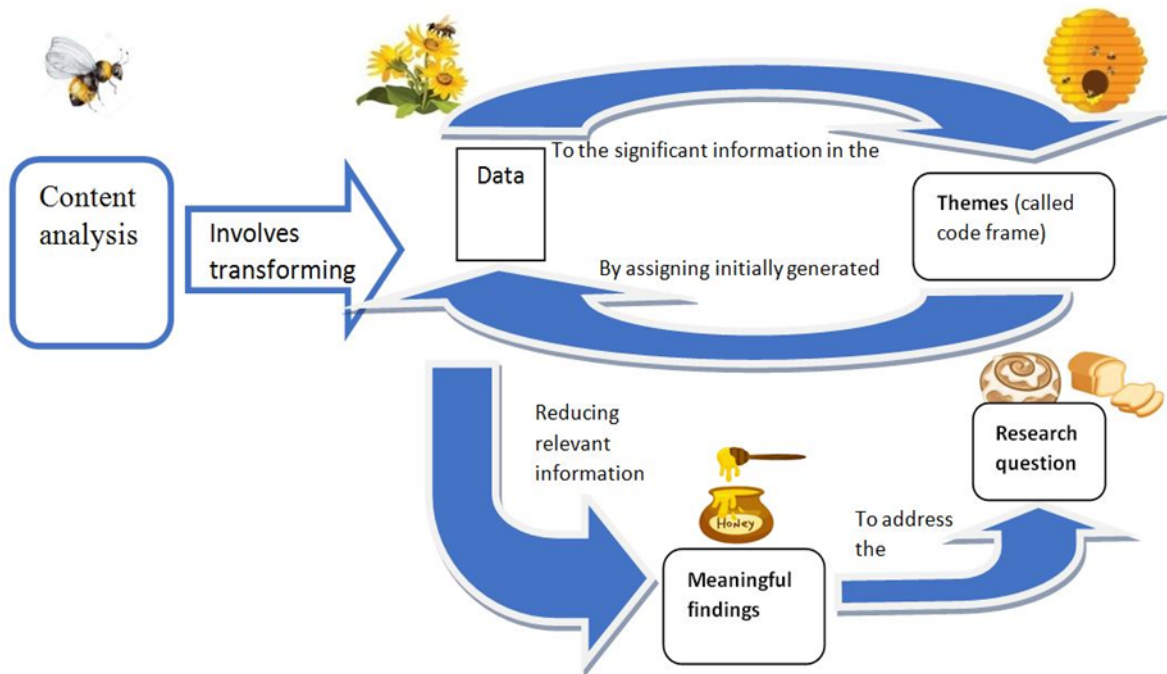
Figure 1. Qualitative content analysis methodology
Source: (Adu, 2017)

3. Results and Discussion

Man-made environmental problems are interconnected as cause and effect to one another. For instance, water pollution and water scarcity (E12) is caused by several other man-made environmental problems, such as agrochemicals (E40), solid waste (E19), plastic pollution (E21), e-waste (E24), heavy metal contamination (E20), pollution through mining activities (E08), the establishment of dams (E09), sedimentation and soil erosion (E07), over-exploitation of natural resources (E01), hazardous waste (E23), intensive farming (E43), global warming and climate change (E27), groundwater contamination (E15), urbanization (industrialization), urban sprawl and settlements(E10) and wetlands or draining of wetlands (E06) (Sivaramanan, 2021). And the effects of water pollution (E12) are eutrophication (E14), biodiversity loss (E05), and disease and food insecurity (E38). Thus, man-made environmental problems are interconnected to one another as causes and effects (Sivaramanan, 2021). The following concept map depicts the interconnected nature of 40 man-made environmental problems based on causes and effects relationship. After a prolonged study from 2013 Dec. – 2019 Jan. with publications (there is no specific reason for choosing this time period for the study) on real-world evidences from interconnections between selected man-made environmental problems the following concept map was published (Sivaramanan & Kotagama, 2019), which is given in figure 2.
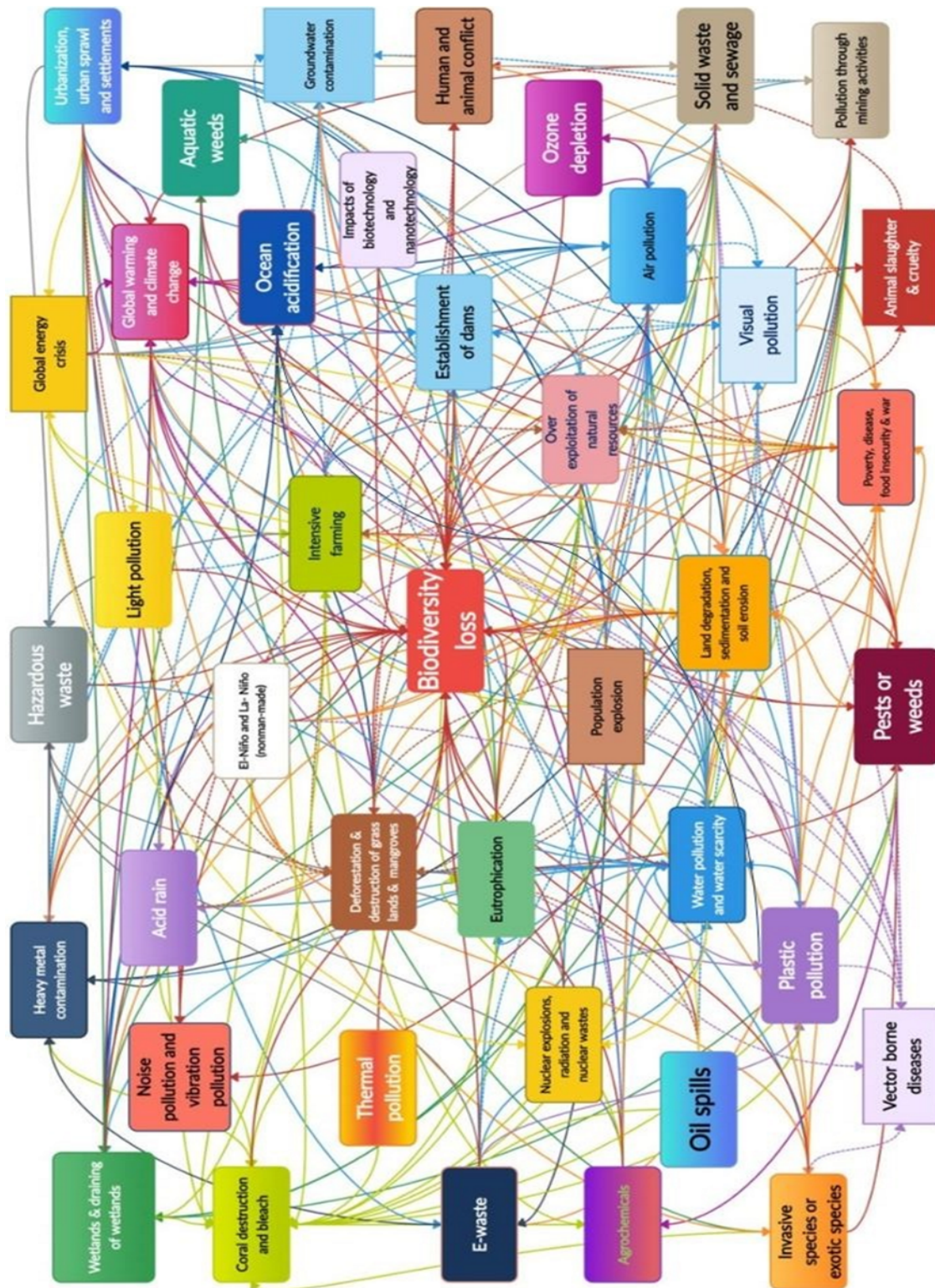
Figure 2. Concept map of interconnected man-made environmental problems based on cause-and-effect relationships

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Similarly , study (Sivaramanan, 2021)illustrated that causes of land degradation, desertification and soil erosion (E07) are deforestation and destruction of mangroves (E28), agrochemicals (E40), pollution through mining activities (E08), overexploitation of natural resources (E01) (excess land usage), intensive farming (E43), heavy metal contamination (E20), water pollution and water scarcity (E12), the establishment of dams (E09), invasive species or exotic species (E42) (e.g. Eucalyptus sp. causes land degradation through its oily litter). Besides, study (Sivaramanan, 2021) depicted impacts of land degradation, desertification, and soil erosion (E07) are poverty, disease, disability, and food insecurity (E38), in this group of problems, land degradation (E07) causes problems, such as food insecurity (E38) (while the disease and disability caused by famine or malnutrition are less pronounced) and biodiversity loss (E05) (poor soil no longer harbor organism and biodiversity). In the aforesaid scenario, twelve environmental issues are directly linked to land degradation, desertification, and soil erosion (E07) (ten causes and two impacts) (Sivaramanan, 2021).

3.1. Identifying keystone environmental problems or keystone links

When solving a man-made environmental problem, if it results in the permanent disappearance of one or more man-made environmental problems, then that mitigated problem can be considered as a keystone environmental problem. For instance, Air pollution causes acid rain, and acid rain is caused only by air pollution, in this case air pollution is a keystone environmental problem because when SOx and NOx air pollution is mitigated, then the acid rain problem gets disappear. However, if more than one environmental problem causes an environmental problem, then none of the causative environmental problems can be considered the keystone, for instance, biodiversity loss is caused by land degradation and competition with invasive species. Here, land degradation is not a keystone environmental problem because even if land degradation is mitigated, competition impact from invasive species continues to fuel biodiversity loss.

Based on the aforesaid scenario eight keystone environmental problems were identified, such as population explosion, air pollution, deforestation, overexploitation of natural resources, global energy crisis, intensive farming, water pollution-water scarcity, and urbanization (industrialization)-urban sprawl.

3.2. Intensive farming as a keystone environmental problem

Intensive agriculture is one of the largest contributors to man-made climate change, accounts for around 12% of total emissions, and a quarter of greenhouse gas emission (S mith et al., 2007). Animal agriculture accounts for 37% of methane emission and 65% of nitrous oxide (FAO /LEAD, 2006). Also, runoff from farms causes eutrophication. Poor living conditions in industrial farms cause animal diseases and animals are said to be subject to cruel handling. Agrochemicals such as pesticides, fungicides, herbicides, and chemical fertilisers lead to toxic effects on waterways and the atmosphere and affect non-targeted biota such as insects, birds, and other animals. Agrochemicals also affect soil microflora and fauna, and cause soil salinization and desertification. High concentration of nitrate in groundwater from chemical fertiliser causes methemoglobinemia (blue baby syndrome). Nitrate and phosphate effluents from excessive chemical fertilisers lead to eutrophication resulted in algal blooms that clogs the fish gills, and increases the biological oxygen demand. Intensive palm oil agriculture causes deforestation in Indonesia and affects orangutan habitats. Intensive farming including slash and burn techniques cause severe biodiversity loss and a threat to indigenous people. According to the department of agriculture (United States), number of factory farms was increased by 230% during the period of 1982 to 2002.

Besides, in the period between 1990 and 2015, pesticide usage worldwide has increased by 73%. Antibiotics and growth hormones used in animal farming also affect humans (Keeling, 2020).

Intensive farming results into problems, such as overexploitation of natural resources, desertification, deforestation, biodiversity loss, animal slaughtering and cruelty, agrochemicals, solid waste and sewage, eutrophication, groundwater contamination, the establishment of dams, water pollution-water scarcity, wetlands or draining of wetland, and hazardous waste from toxic pesticide chemicals. If intensive farming comes to an end, then problems such as resource depletion, desertification, deforestation, animal slaughtering and cruelty, agrochemicals, eutrophication, groundwater contamination, wetlands, and biodiversity loss (to a certain extent) get eliminated (figure 3).

3.3. Evidence 1: Intensive farming causes agrochemical pollution

Intensive farming with the use of chemical fertilizers and pesticides may result in several environmental issues such as eutrophication, land degradation- sedimentation- soil erosion, loss of biodiversity, overexploitation of natural resources, heavy metal contamination, water pollution, groundwater contamination, hazardous waste, deforestation, air pollution, global warming, solid waste and sewage, dam construction, coral destruction, animal slaughter, and cruelty and food insecurity diseases and poverty. However, based on the concept diagram (fig ure2) if intensive farming techniques are abandoned and replaced by organic farming or permaculture techniques then agrochemical problems get cease completely. Thus, intensive farming is a keystone environmental issue.

According to Feuerbacher, Luckmann, Boysen, Zikeli, & Grethe (Feuerbacher, Luckmann, Boysen, Zikeli, & Grethe, 2018), the study revealed that Bhutan's large-scale conversion to 100% organic agriculture by desolating the agrochemical methods resulted in 24% lower yields than conventional yields. The study also found a considerable reduction in Bhutan's GDP, substantial welfare losses, particularly for non-agricultural households, and adverse effects on food security. The reduction in agricultural yield was largely compensated by imported foods from India. And this situation also weakened the country's cereal self-sufficiency. Though soil phosphorus and potassium remained unchanged soil nitrogen levels gone down by (-22.4%) because nitrogen release from animal manure was too slow. However, the study also suggested overcoming these pitfalls Bhutan should improve fertilization management, crop protection, and integration of livestock to obtain better yield as truly holistic, organic farming. Thus, Bhutan's present agriculture policy and its implementation revealed that the absence of intensive farming brought the use of agrochemicals to a halt. Thus, it is clear that intensive farming is a keystone man-made environmental problem (based on the definition). However, increasing food demand as the result of an increasing population may question Bhutan's 100% organic policy in the future and it may further increase food insecurity and poverty in the country. Thus, the population explosion acts as the precursor link of major man-made environmental problems.

3.4. Evidence 2: Intensive farming causes water pollution and scarcity

According to FAO (FAO, 2011) as cited in (Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany, 2017) "agriculture accounts for 70% of total global freshwater withdrawals on average, thus, agriculture is the largest water user in the world." and "these amounts can reach as much as 95% in some developing countries" (FAO, n.d.) as cited in (Water for

Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany, 2017). Besides, "agriculture is the major source of water pollution such as nutrient loading, pesticide, and other contamination" (Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany, 2017).

3.5. Evidence 3: Intensive farming causes deforestation

According to the report 'Agriculture is the direct driver for worldwide deforestation' (Agriculture is the direct driver for worldwide deforestation, 2012), "agriculture is estimated to be the direct drive for deforestation. 80% of deforestation worldwide is due to agriculture or intensive farming".
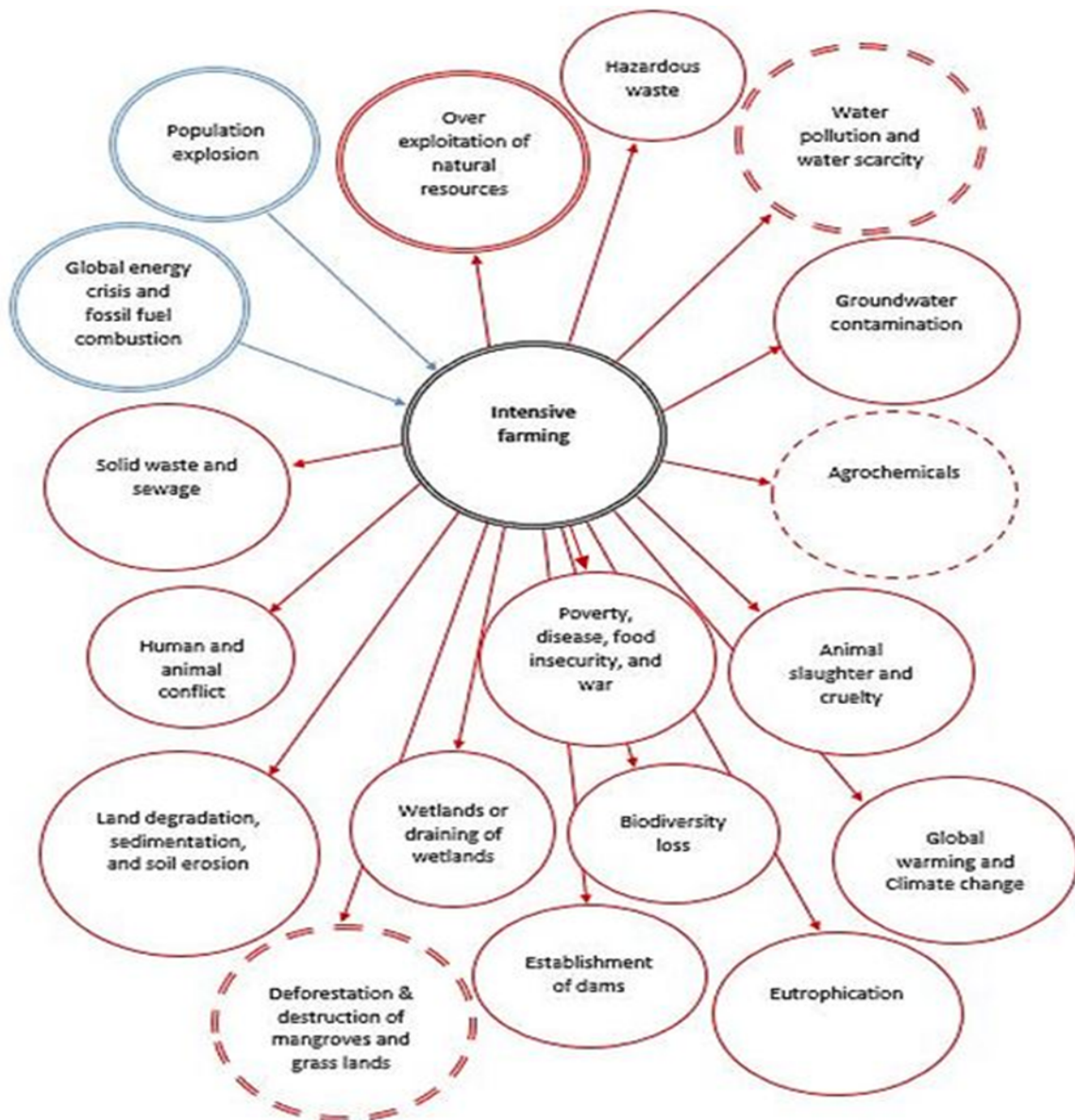
Figure 3. Intensive farming as keystone environmental problem with the disappearance of agrochemicals, water pollution-water scarcity, and deforestation on its mitigation (hypothetical diagram)

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[In the figure black circle is the problem being examined, blue circles are cause man-made environmental problems, red circles are effect man-made environmental problems, double lined circles are keystone man-made environmental problems, and circles with dashed lines (either single or double lined) are the man-made environmental problems that disappear when the problem being examined (black circle) is mitigated]

In this way remaining seven keystone environmental problems were supported by real-word examples from published papers. (The concept flowcharts are given below: figures 4-10)
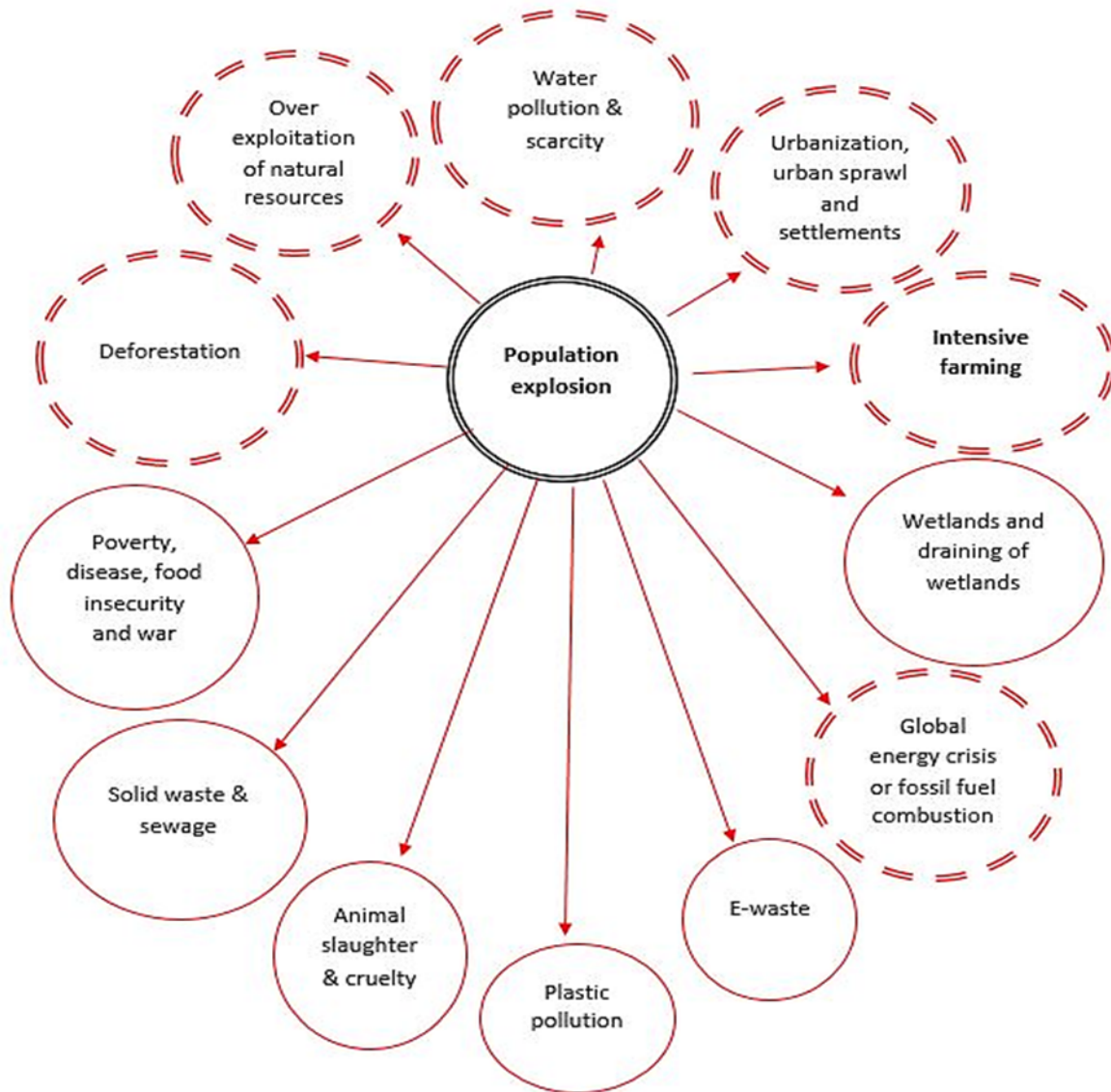
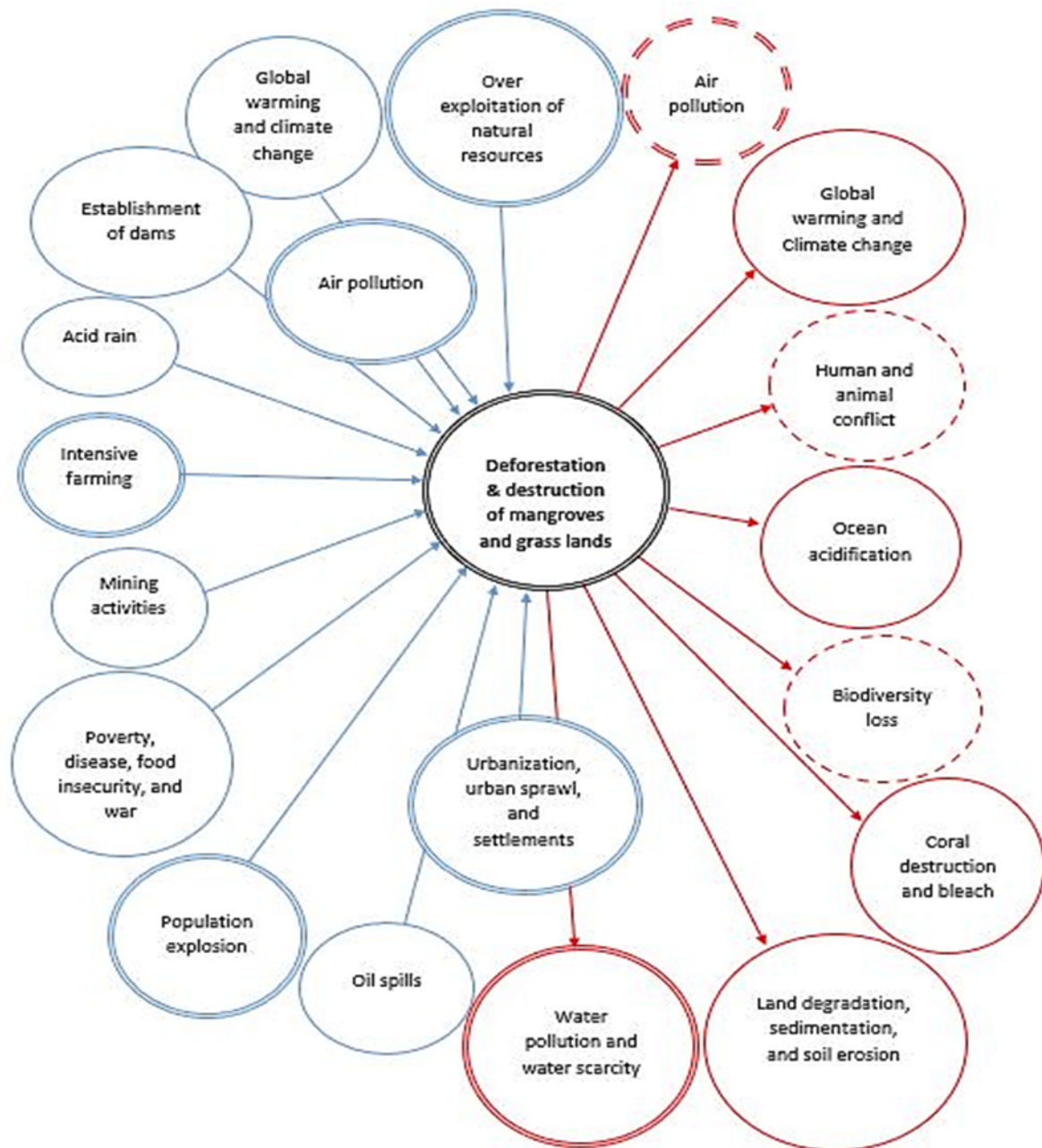Figure 4. Population explosion as keystone environmental problem

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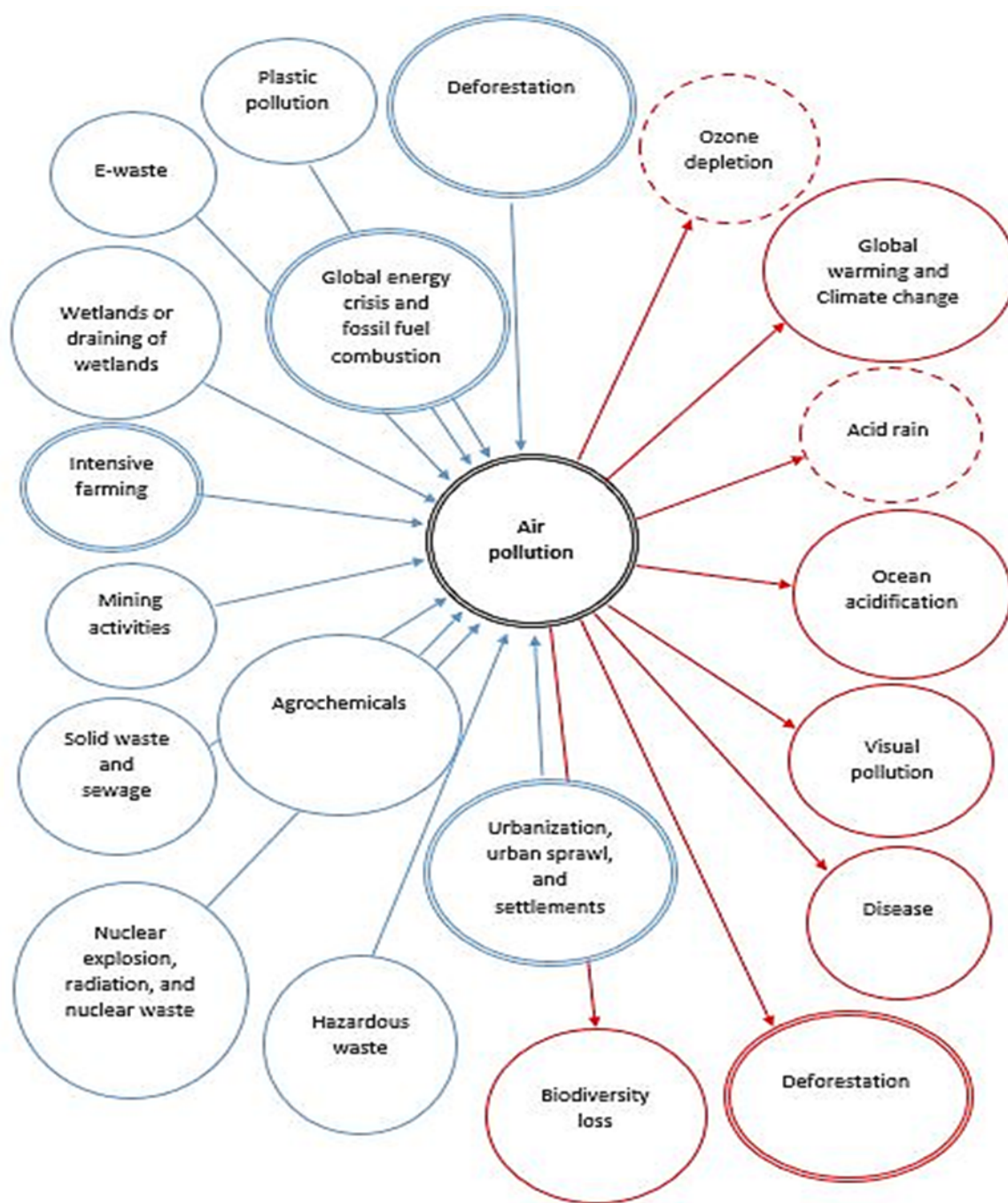Figure 5. Deforestation as keystone environmental problem

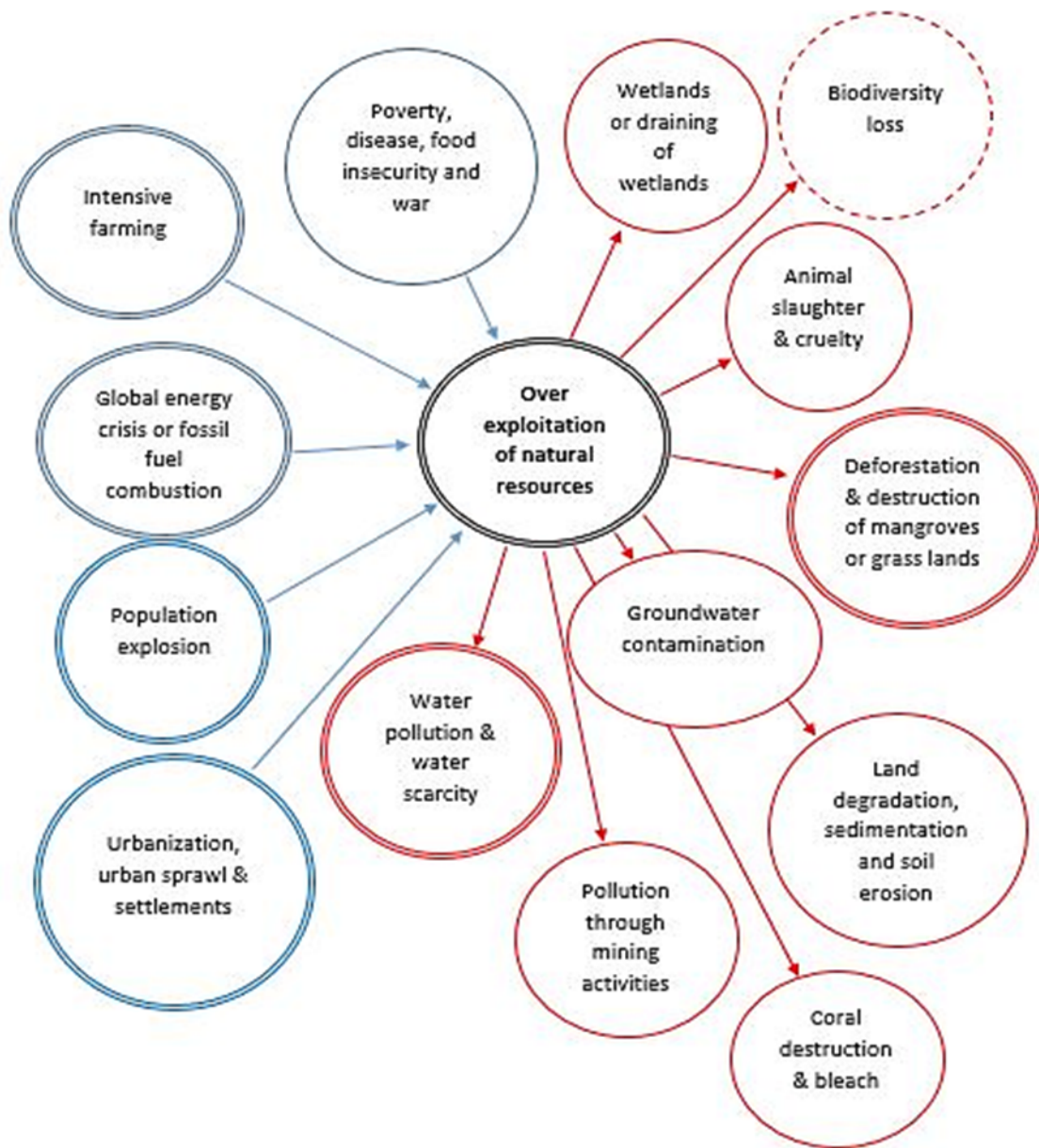Figure 6. Air pollution as keystone environmental problem

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Figure 7. Overexploitation of natural resources as keystone environmental problem
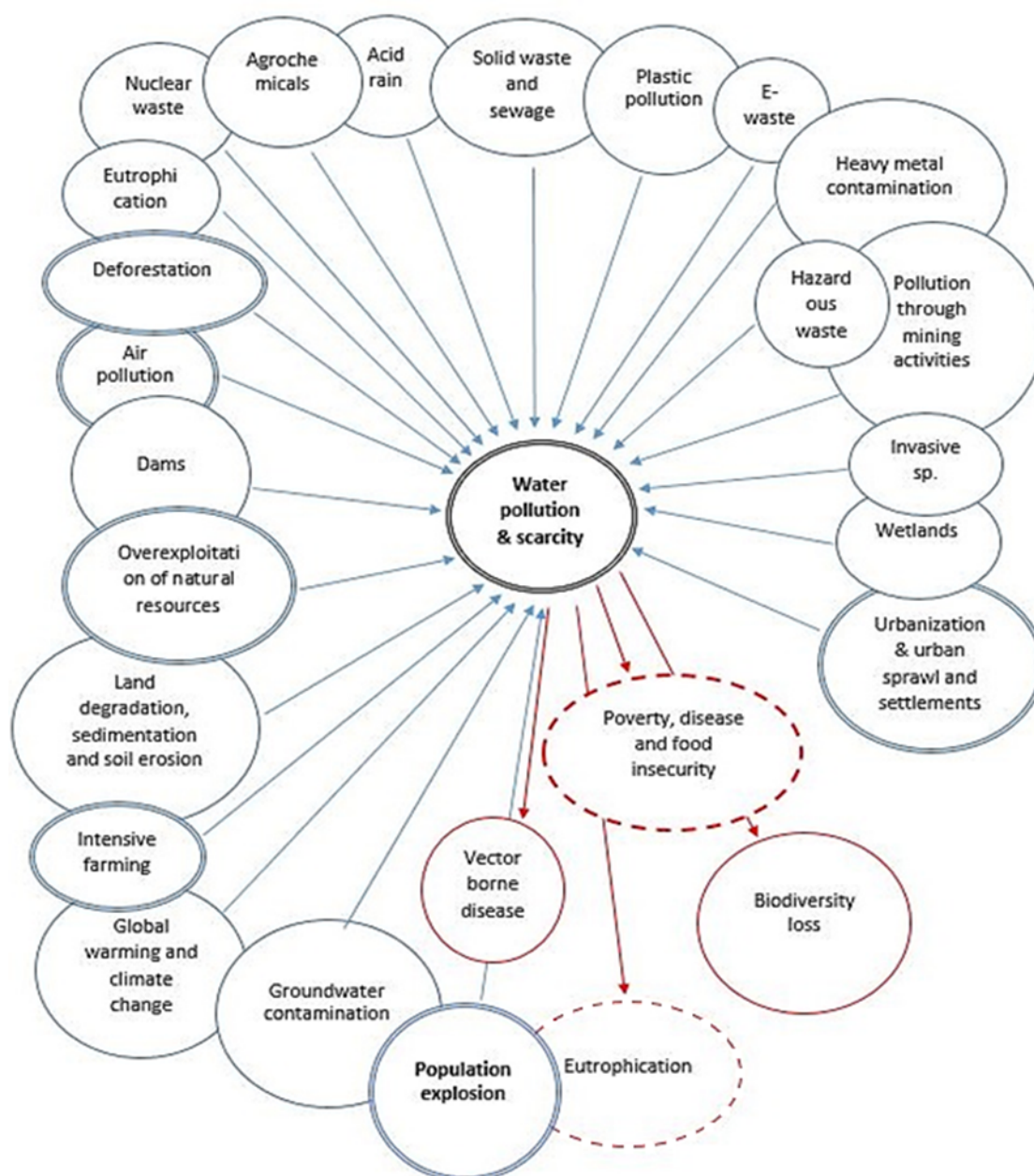
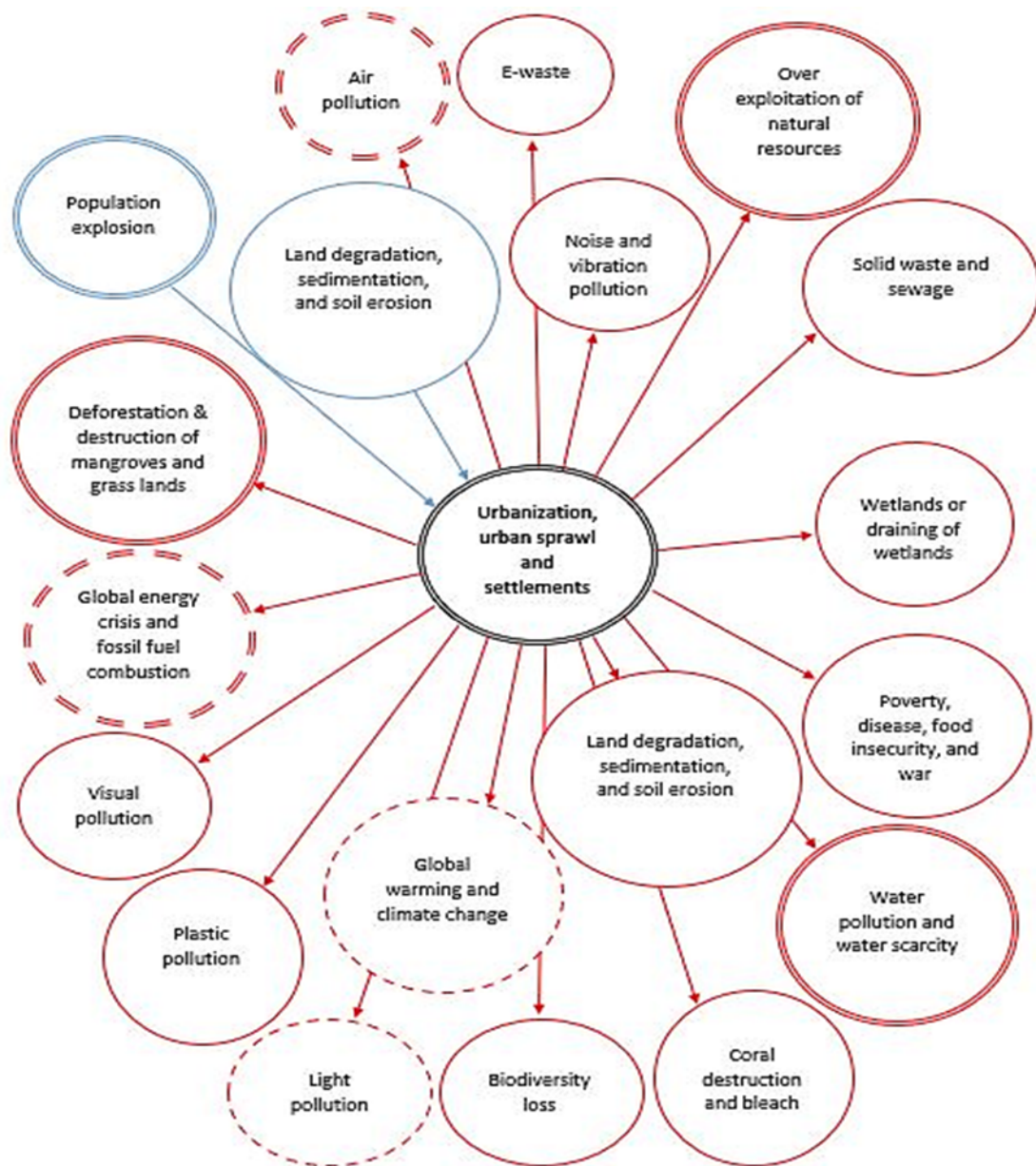Figure 8. Water pollution and scarcity as keystone environmental problem

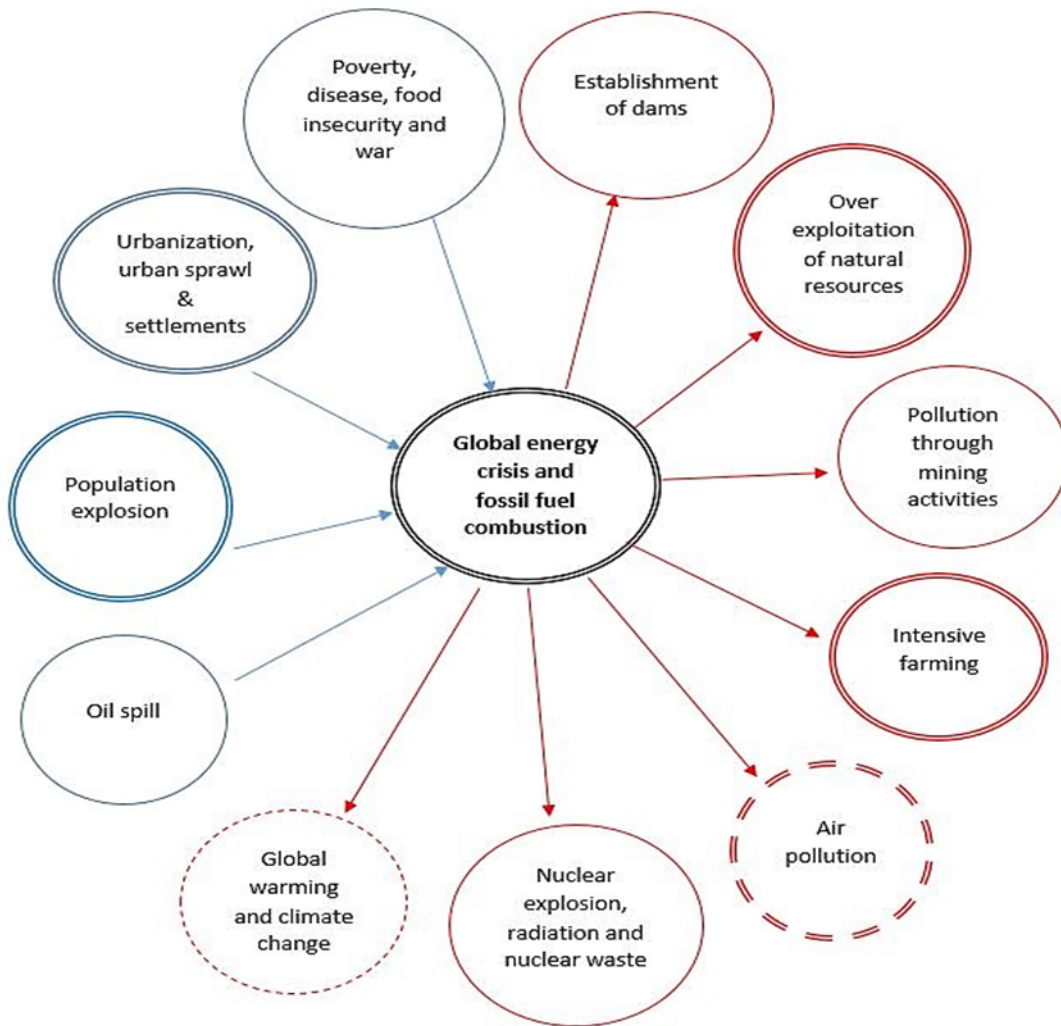Figure 9. Urbanization (industrialization), urban sprawl and settlements

Figure 10. Global energy crisis and fossil fuel combustion as keystone environmental problem

[In these hypothetical flowcharts black circle is the problem being examined, blue circles are cause man-made environmental problems, red circles are effect man-made environmental problems, double lined circles are keystone man-made environmental problems, and circles with dashed lines (either single or double lined) are the man-made environmental problems that disappear when the problem being examined (black circle) is mitigated]. At the end, the hypothetical path of the keystone environmental issues was drawn as given below (figure11).
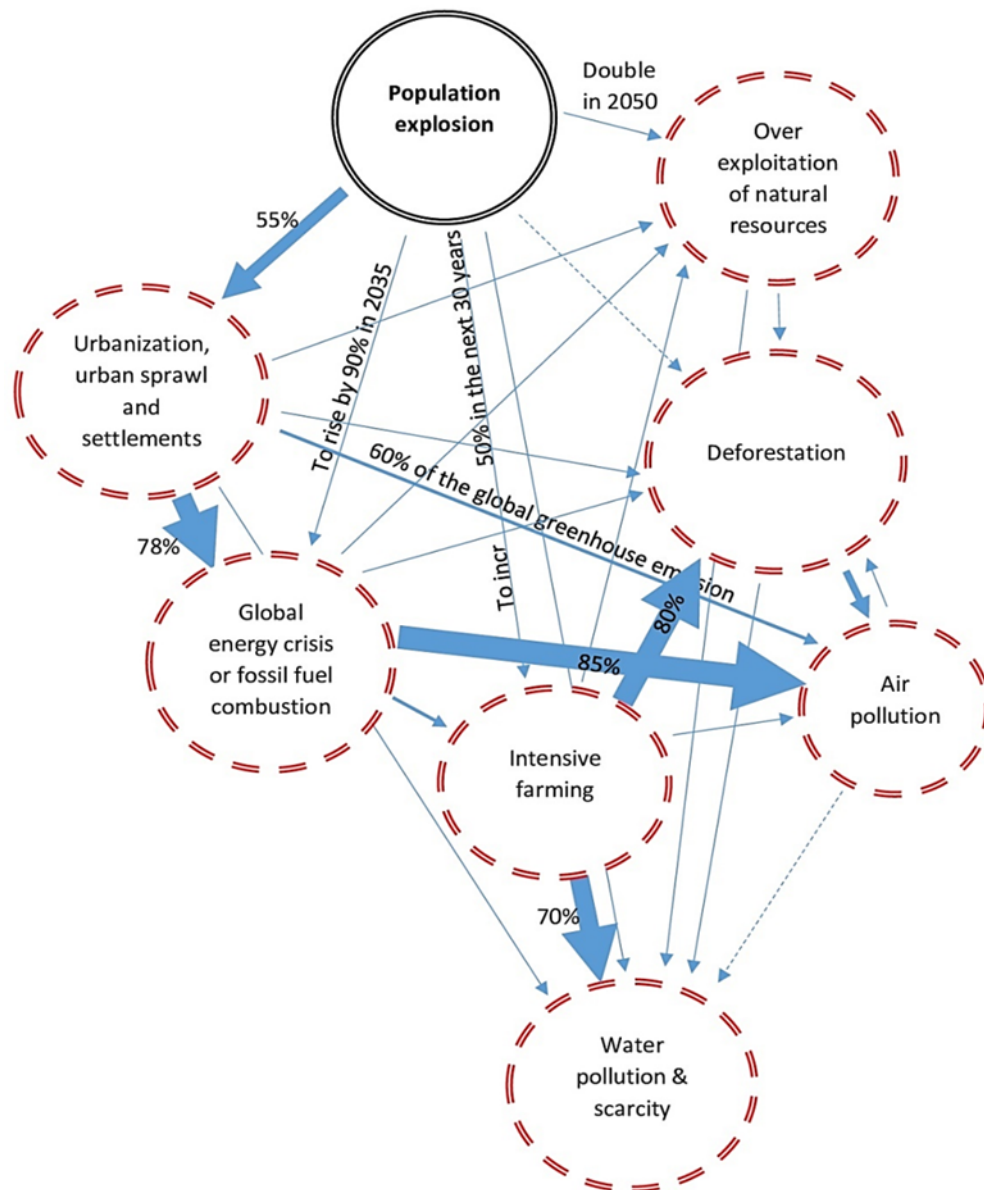
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Figure 11. Path of the keystone man-made environmental issues (hypothetical diagram)

[In the figure black circle is the problem being examined, red circles are the effect man-made environmental problems, double lined circles are keystone man-made environmental problems, and circles with dashed lines are the man-made environmental problems that disappear when the problem being examined (black circle) is mitigated]

- According to the United Nations ("Department of Economic and Social Affairs", 2018), today **55%** of the world's population lives in urban areas.
- According to "UNEP" ("UNEP", 2017), overexploitation of natural resources expected to **double by 2050** due to the increasing population and its growing needs.

- According to "OECD report" ("OECD report", 2011), "global energy demand is rapidly increasing, arising from population and economic growth, thus, energy demand growth is projected to rise by **90%** in 2035.
- According to Harvey (Harvey, 2019), the author has raised the question that "Can we ditch intensive farming - and still feed the world?" In brief, global food production must increase by **50%** in the next 30 years.
- According to UN-Habitat, **60%** of the global greenhouse emission is from urban cities (Climate Action Summit, 2019)
- Agriculture is the direct driver for worldwide deforestation, **80%** of deforestation worldwide are due to agriculture or intensive farming (Agriculture is the direct driver for worldwide deforestation, 2012).
- According to FAO (FAO, 2011) as cited in (Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany, 2017), agriculture accounts for **70%** of total freshwater withdrawals on average worldwide.
- According to "OECD report" ("OECD report", 2011), fossil fuel combustion accounted for **84%** of global greenhouse gas emissions in 2009.
- According to International Energy Agency (IEA) WEO-2016[b]. Special Report Energy and Air Pollution (International Energy Agency (IEA) WEO-2016 Special Report Energy and Air Pollution, 2016) as cited in (Perera, 2018) "energy-related fossil fuel combustion in high and middle-income countries and biomass burning in low-income countries account for most of the global air pollution, generating **85%** of airborne breathable particulate pollution and almost all sulphur dioxide and nitrogen oxide emissions to the atmosphere." It is believed that most of the global warfare were evolved from environmental conflicts over limited resources, transboundary pollutant emissions and other impacts of increasing human population. Thus, future study can be made on how the keystone environmental issues result into both international and intranational environmental conflicts? (That will be discussed in our next paper).

Conclusion

All man-made environmental problems are interconnected based on cause-and-effect relationships in a hypothetical situation where human adaptability factors such as economic, social and political factors are absent. Study was conducted using qualitative content analysis methodology. When mitigating a man-made environmental problem, if it results in the permanent disappearance of one or more man-made environmental problem/s, then that mitigated problem can be considered as a keystone environmental problem, Following eight man-made environmental problems were identified as keystone environmental crises by the study, such as air pollution, deforestation, population explosion, overexploitation of natural resources, global energy crisis, intensive farming, water pollution-water scarcity, and urbanization (industrialization)-urban sprawl-settlements.

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