DOTS AND PATTERNS IN NATURAL LANDSCAPE ECOSYSTEM

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Introduction

In Islam, any actions with the intention to improve, enhance and enrich the environment (Tahsin al- ardh) is considered as part and parcel towards achieving environmental sustainability objectives as it will ensure the ecological balanced (Mizan) of the earth. As stated in the Holy Quran, man is called to preserve this equilibrium, to be moderate in everything and to avoid any actions that would cause harm to nature, *"And the Firmament has He raised high, and He has set up the Balance [of Justice], in order that ye may not transgress [due] balance. So establish weight with justice and fall not short in the balance"* (Al-Rahman: 7-9).

Dots and patterns as ecological indicator signatures

Taking the analogy from dot to dot games during pre-school and kindergarten to reveal the final picture or pattern, the scientific analysis of natural phenomena is somewhat likewise. Individual dots have no meaning, but the meaning is provided by patterns or connected dots. Therefore, by discovering and understanding the patterns of nature, we can understand, predict and forecast the nature behaviour. Dots are the set of data that were collected and analysed to produce patterns or hypotheses which later can be translated into models and theories. Starting from the evidence of dots, different discipline or body of knowledge may come up with a different set of patterns or theories made up in their field of research. Some patterns are easy to predict from the dots, but the most genuine one is the dots that revealed many patterns.

Although we cannot fully explain how complex nature's work, one thing for sure we know that nature itself is a compilation of signs pointing to the Divine. Paradoxically in science, any theory must have the ability to be predicted, tested and critically analysed to get explanation or conclusion. This body of knowledge has been given to mankind through perception and observations that must be used wisely and intelligently to avoid destructing Allah's creatures on the earth. Man is also has been given imperative responsibility to build the earth and utilize its resources with a sense of justice ('Adl) to oneself, to other fellow mankind and to other creatures without harming other creatures as the Messenger of Allah (PBUH) said, *"There should be neither harming (darar) nor reciprocating harm (diraar)"* (Hadith: 32).

Therefore, since ecological indicators were recognized due to its ability to indicate healthy and unhealthy environment; this application should be further studied and applied especially in the Islamic built environment body of knowledge as well as their key players. Subsequently, in a way to achieve our position as *Khalifah* on earth as mentioned in the Quran, *"It is he [Allah] that has appointed you [mankind] as vicegerent in the Earth..."* (Al- Fatir: 39), further research on ecological indicators will generate a strong connection between one's faith (*Iman*) and environment as a sign of the existence of Allah as well as to achieve the Islamic taught of sustainable development. On top of that Islam teaches mankind to seek for knowledge through hearing, seeing and reasoning with the guidance of the Quran and As-Sunnah as Allah says, *"Travel through the earth and see how God did originate creation"* (Al-`Ankabut: 20). In fact, the Quran also mentioned on the natural science, psychology, history, geography, sociology, astronomy and other fields of knowledge (*'Ilm*). Allah has created this universe with perfect wisdom (*Hikmah*) and for very significant purposes which become a sign for the believers. *"Not without purpose did We create heaven and earth and all between! That were the thought of Unbelievers! But woe to the Unbelievers because of the Fire (of Hell)!"* (Sad: 27) and, *"Not for (idle) sport did We create the heavens and the earth and all that is between!"* (Al- Anbiya':16).

Eco-Indicator Agents

Early humans used indicators like seasonal migratory movements of animals or flowering season to provide insight into environmental changes. Indicators are referred to as parameters, measures, variables or measurement endpoints whereas ecological indicator is a sign or signal that revealed a complex message in a simplified pattern or is a collection of variables that

describes the health status of an ecosystem or one of its critical components. Ecological indicators have several purposes as they can be used to assess the conditions of the environment, to monitor trends over time or to provide an early signal of changes. More specifically, they can be used to detect and summarize patterns of the ecosystems, for instance, such as using plants as indicators for physical processes, changes to soil conditions, and other factors to determine to change environmental conditions, such as water clarity or air quality.

Phytoindicator agent for soil fertility

One of the common natural phenomena that can be used in landscape ecology body of knowledge to detect soil fertility or water level in the soil is by looking at the growth of short and tall grasses. The abundance of short grasses indicates harsh environment, low water content, hot and dry condition and that soil is considered not suitable for agriculture or any landscape project whereas a combination of tall and short vegetation indicates that soil is fertile and suitable for any landscape or planting activities. Among other types of plant indicators for different types of soil fertility based on the previous report as detailed by Shukla and Chandel, (2006) are

Table 1: Phytoindicator agents for different signatures of soil quality and fertility

Eco-indicator Agent	Category	Eco-Signature
Andropogon scoparium	Weed	Sandy loam soil
Butea monosperma	Tree	High alkaline soil
Capparis decidua	Shrub	Alkaline soil
Lippia nodiflora	Weed	The high content of nitrate
Peganum harmala	Shrub	High nitrogen and salts content in a soil
Pinus sp. and Juniperus sp	Tree	Uranium-rich soil
Prosopis cineraria	Tree	Good soil
Rumex acetosella	Weed	Acidic soil with a high content of nitrate
Salvadora oleoides	Tree	High calcium and boron content in the soil
Zizyphus nummularia	Tree	Good soil

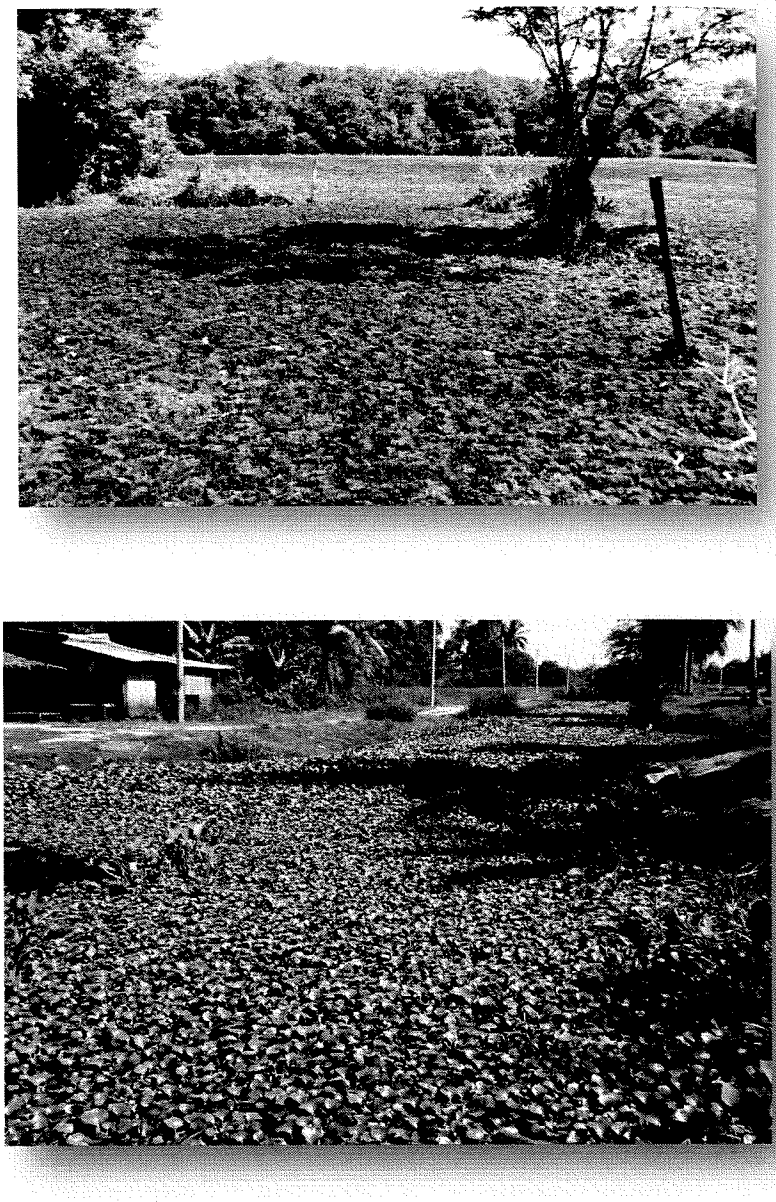

Figure 1: The abundance of *Salvinia natans* (top) and *Eichhornia crassipes* (bottom) as indicators for low water quality index.

Phytoindicators for heavy metals contaminant

Certain aquatic plant communities indicate water quality index or level of contaminants. Some of the potential eco-indicator agents are listed below as summarised by Prasad et al. (2005, 2003):

Table 2: Different aquatic plant species as eco-indicator agent for heavy metals contaminant

Aquatic plant species	Indicator
Azolla pinnata	Cd, Cr, Zn
Bacopa monnieri	Hg, Cr, Cu, Cd
Ceratophyllum demersum	Cd, Cu, Cr, Pb, Hg, Fe, Mn. Zn, Ni, Co
Eichhornia crassipes	As, Cd, Co, Cr, Cu, Al, Ni, Pb, Zn, Hg, P
Elodea canadensis	Cu, Pb, Cd, Zn, Cr, Ni
Eriocaulon sexangulare	Hg, Pb, Cd, Fe
Hydrilla verticillata	Hg, Fe, Ni, Pb
Lemna minor	Mn, Pb, Ba, B, Cd, Cu, Cr, Ni, Se, Zn, Fe
L. gibba	Cu, Cd
Ludwigia natans	Hg
Myriophyllum spicatum	Cd, Cu, Zn, Pb, Ni, Cr
Nymphaea alba	Ni, Cr, Co, Zn, Mn, Pb, Cd, Cu, Hg, Fe
Nymphoides germinate	Cd, Cu, Pb, Zn
Phragmites karka	Cr
Pistia stratoites	Cu, Al, Cr, P, Hg
S. natans	Pb, Cr
S. molesta	Hg
Scirpus lacustris	Cr
Spirodela polyrhiza	Cr
Typha latifolia	Ni, Cr, Co, Zn, Mn, Pb, Cd, Cu, Hg, Fe

Figure 2: *Nelumbo nucifera* is a good ecological indicator agent for a lead contaminant.

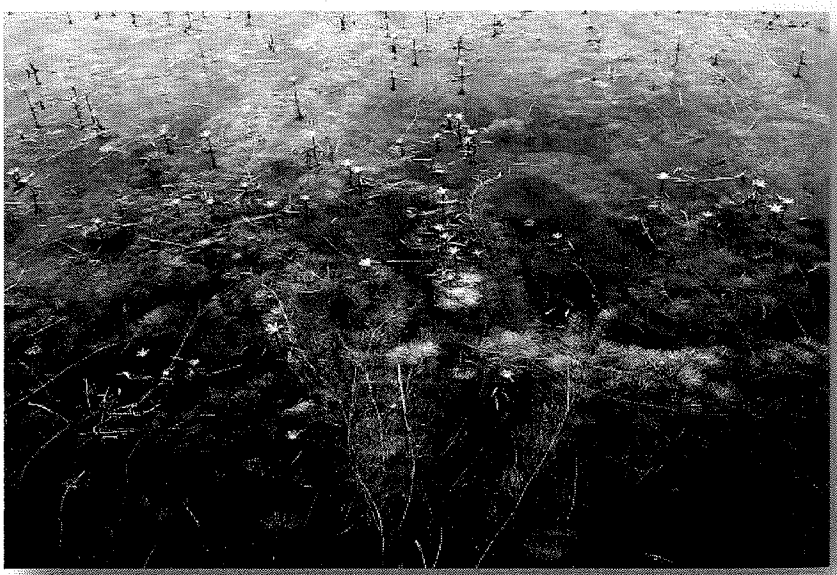

Figure 3: *Cabomba fuscata* invasiveness as indicator for copper contaminant.

Phytoindicators for types of ecosystem

An ecosystem consists of the biological community that occurs in some locale, and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems such as a pond, a forest, an estuary, grassland, river or lake. Each type of this ecosystem will have a specific protagonist or plant species as listed below:

Table 3: Phytoindicator for a specific type of ecosystem in Malaysia

Type of ecosystem	Species Indicator
Heath forest	*Drosera, Myrmecodia, Hydnophytum, Nepenthes, Melaleuca, Utricularia, Dischidia* and *Gymnostoma.*
Mangrove forest	*Avicennia sp., Sonneratia sp., Rhizophora sp., Bruguiera sp., Nypa fruticans* and *Ceriops tagal*
Beach forest	*Casuarina equisetifolia, Calophyllum inophyllum, Eugenia gramdis, Terminalia catappa, Ipomea pes-caprae, Vigna marina, Spinifex littoreus, Scaevola sericea* and *Vitex trifolia*
Limestone forest	*Monophyllaea, Justicia, Begonia, Impatiens, Boea, Chirita, Paraboea* and *Maxburrettia rupicola*
Peat swamp forest	*Amoora rubiginosa, Anisoptera marginata, Cratoxylon arborescens, Koompassia malaccensis, Shorea dealbata, Hopea mengarawan,Gonystylus bancanus, Pandanus amaryllifolius, Pandanus fascicularis, Zalacca conferta* and *Cyrtostachys lakka*
Lowland Dipterocarp Forest	*Anisoptera sp., Dipterocarpus sp., Dryobalanops sp., Hopea sp., Neobalanocarpus sp., Shorea sp.* and *Parashorea sp.*
Hill Dipterocarp forest	*Shorea curtisii* and *Eugeissona triste*
Upper Dipterocarp forest	*Shorea platyclados, Agathis alba* and *Calophyllum spp,*
Montane oak forest	*Quercus, Lithocarpus, Castanopsis, Acer niveum, Agathis alba, Adinandra, Calophyllum, Canarium, Dacrydium, Eugenia, Garcinia, Podocarpus, Argostemma, Sonerila, Didymocarpus, Aeschynanthus* and *Poikilospermum*
Montane ericaceous forest	Liverworts, mosses like Sphagnum spp., filmy ferns, oaks, epiphytic orchids and rhododendron are common and frequent
Regenerated forest	Dominated by *Trema-Macaranga-Mallotus* communities

Figure 4: *Rhizophora* sp. as phytoindicator for mangrove ecosystem

Figure 5: *Melaleuca cajuputi* as phytoindicator for Heath forest ecosystem

Phytoindicators for a marked abiotic environment

Halophytes species such as *Sonneratia*, *Avicennia* and *Rhizopus* indicate marine alluvial or water-logged saline soils whereas *Nelumbo*, *Typha*, *Phragmites* and *Nymphaea* indicate fresh water bodies or swampy condition. Other species such as *Calotropis*, *Agave*, *Opuntia* and *Scaveola* indicate poor or very low moisture content in the soil. Plant species such as *Leucobryum*, *Ectropothecium*, *Rhodobryum*, *Pogonatum*, *Strobilanthes*, *Impatiens*, *Monotropa* and *Neottia* indicate the presence of high organic matter or litter in the soil. *Imperata cylindrical* and *Vetiveria zizanioides* indicate clayey soils, *Casuarina equisetifolia*, *Ipomea pes-caprae*, and *Vigna marina* indicate sandy soil (Razanah, 2015; Prasad, 2015).

Phytoindicators for minerals

The most intriguing application of eco-indicators is their ability to indicate the presence of minerals in the soil such as gold and diamond. Different localities will have different types of species. These phytoindicators are called metallophytes, and their ability to grow on specific metals are listed below as detailed by Shukla and Chandel, (2006):

Table 4: Metallophytes and their ability as eco-indicator agent for minerals

Type of mineral	Species Indicator
Diamond	*Vellozia candida*
Gold	*Equisetum arvense, Lonicera confusa, Alpinia speciosa, Thuja*
Silver	*Eriogonum ovalifolium*
Mercury	*Stellaria setacea*
Uranium	*Astragalus species*
Selenium	*Neptunia amplexicaulis, Stanleya pinnata*
Copper	*Salvinia natans, Viscaria alpina, Gypsophila patrini*
Zinc	*Viola lutea*
Boron	*Salsola nitrata*
Cobalt	*Nyssa sylvatica*
Nickel	*Lychnis alpina*
Lithium	*Lycium Juncus, Thalictrum*
Petroleum Deposits	Protozoans under Fusulinida order

Fauna as ecological indicator agents for ecosystem status

Other than flora or plant species, there is another species or known as fauna that can be categorized as ecological indicator agents such as bird and mammal species, reptiles and amphibians as well as insects. Bird community

composition reflects interspecific dynamics and population trends. Other than relative to other taxa, birds are also attractive as ecological indicators due to its readily sampled and their taxonomy is well known. Birds also can be a focus of societal concern, for example, the condition of bird communities across the region and anticipated reflecting the overall structural, functional and compositional condition of ecosystems. Birds species also have a negative inclination that often affected by land-use changes, forestry and agriculture, and the habitats of these species have to be observed. Species that are vulnerable to changes in land-use can be used as target species in spatial and physical planning (Mortberg and Wallentinus, 2000). Ecologically, sites in poor conditions were dominated by either urban or agricultural bird communities. Forested sites in good and excellent condition will support different bird communities and ground-level vegetation attributes, but it could not be separated by land cover composition alone. Birds exhibit numerous characteristics that suggest their potential as ecological indicators at large scales (O' Connell et al., 2000). For example, many species' distributions are affected by habitat fragmentation or other habitat structure parameters. Many birds are occupying high trophic levels and may integrate functional disturbance at lower levels. As a conclusion, we may see that the changes in the environment have a strong relation with the ecosystems. There are many indicators which have been used to examine the impacts of the world climate changes. Nonetheless, bird guilds can be considered as one of the most diverse groups of ecosystem agents functioning as biodiversity changes indicator. A balanced (*Mizan*) ecosystem is achieving by considering all range of species which depends on each other to survive but not to disturb the nature.

Environmental indicators are an attempt to reduce the information overload, isolate key aspects of the environmental condition, document large-scale patterns, and help determine appropriate actions. Typically, ecological indicator species tend to be from the macro flora and macro fauna, especially aquatic macro invertebrates, fish, birds, and vascular plants. The primary reasons for their use are: (a) relative ease of identification, (b) interest to the public, (c) relative ease of measurement, (d) relatively large number of species with known responses to disturbance, and (e) relatively low cost. Indicator species are used in three distinct ways: (a) to reflect the biotic or abiotic state of the environment; (b) to reveal evidence for the impacts of environmental change; or (c) to indicate the diversity of other species, taxa, or communities within an area. The first two reflects the common uses of indicators as measures of condition and the diagnosis of the potential cause of environmental change. The third expands the concept of indicators to

incorporate the idea of a single species serving as a surrogate for many other species. This idea has been largely untested and has been the focus of much debate and criticism in applications. In summary, focal species represent those selected as a focus for a specific investigation or purposes.

Potential Applications of Eco-Indicator Agents in Landscape Ecology

The overwhelming increase of aquatic ecosystems pollution either inorganic or organic throughout the developing countries becomes increasingly evident. This ecological problem usually coincides with rapid industrialization and urbanization contributed by mobile leachates resultant from open dumps, industrial discharges (chemical and petro chemical), urban-storm water runoff, and agricultural drainage (pesticides and herbicides) (Onwughara et al., 2011). This will not only leads to severe ecological and environmental problems but also potentially pose serious health hazards to human even with the least amount of exposure due to their accretion in the human food chain. The conventional membrane filtration technology for large volume water treatment method such as ion exchange, reverse osmosis, microfiltration, precipitation, or flocculation can be considered prohibitively expensive (Aksorn and Visoottiviseth, 2004) to be afforded and applied especially for developing countries like Malaysia. Membrane filtration technology system, for instance, may require arduous maintenance such as backwashing operation on a regular basis to avoid fouling and to increase its feasibility period. Furthermore, it is less promising in long-term cost-wise due to its constant needs for operators (labour force cost) to control its filtration process and possibly the need for membrane replacement when fouling occurs. This, in turn, creates a huge gap and limitations for water monitoring and treatment efforts. Therefore, it can be agreed that there is an urgent need for better water resources development and management which can be achieved through innovative green technologies to address this issues. Fortunately, landscape ecology through Green technology approach is currently among widely discussed effective and affordable technological solution used to trace environmental imbalance and accumulate inactive metals and metal pollutants from contaminated soil and water. This technology is not only environmentally friendly but also potentially cost-effective. Presently, the study on phytotechnology by using macrophytes to treat water body contamination is still on-going and has shown positive result mostly contributed by the outlined factors identified to affect the substantial metals uptake by plants. One of the key aspects of the acceptance of phytotechnology

pertains to the measurement of its performance, ultimate utilization of by-products and its overall economic viability.

Aquatic plant species can be fully utilized as an effective tool to detect excessive nutrients in water bodies that might otherwise be difficult to detect. The effort of environmental assessment initially focused on picking up a strong and subtle source of pollutants factor such as chemical emissions. However, they suggested that it is difficult to measure and significant alteration of the environmental condition resulted when monitoring through unknown and combined pollutant factors. Subsequently, monitoring efforts began experimenting using ecological receptors since they can trace even subtle and unknown stressor that contribute to the environmental pollution. It is also because the natural environment has always been viably available resources for a human being to sustain their livelihood. An indicator is suggested as insights that convey a complex message potentially attained from various sources. However, by using controlled indicator based on specific studies and monitoring, set of particular signals or information can be acquired in a simplified and useful manner. Whereas there are various definitions of 'environmental indicator', however, most of them underline environmental indicator as a selected quantifiable or numerical variable usually done through public and private initiatives to describe, examines, and presents scientific information and its significance that addresses a variety of environmental issues. Such scientific information characterized as the environmental indication could be the quality and condition of the air, water, land, and ecosystems on various geographic scales, and related human health. The sets of indications attained may reflect biological, chemical or physical attributes of environmental condition that can illustrate current status of the environment and to forecast significantly for future actions plan or considerations. On the other hand, the definition of phytoindicator could be narrowed down as sign or signals of environmental conditions attained from monitoring specific plant species or plant community. As stated by Norton et al. (1992) in Framework for Ecological Risk Assessment, environmental indicators must provide relevant information based on the specific assessment questions, which are developed to address the current environmental management issues.

Conclusion

Dots and patterns derived from the relationship between plants and nature can be used as an ecological indicator for specific purpose or action. In a plant community, some plants are dominant and found in abundance. The

most important characteristics of the eco-indicator agent are the plants must be in community, dominant and abundance to have a full impact on the habitat. This natural phenomenon also can be used to assess past or to predict future status of the environment. The knowledge of ecological indicators can be useful tools to determine soil and water quality, types of contaminant, the presence of particular mineral or metal as well as global climate changes. In short, the ecological indicators discipline will develop our understanding (*Ilmnafi'*) towards environmental management, which may mitigate preserve the environment as a trust (*Amanah*) given, consequently achieving the level of sustainability in the 'eyes' of Allah. Hence, it is very crucial to choose the best path (*Wasat*) in planning and developing our earth. This study may also contribute to various fields in many ways such as:

i. Create awareness of the environmental issues among environmentalists, professionals and public people from multiple disciplines.

ii. Develop an understanding of the importance of ecological approaches in contributing to achieving sustainable development goals.

iii. Introduce new knowledge and new technologies of environmental approaches as support for environmental conservation and preservation.

iv. Develop better landscape ecology management practices besides promoting the importance of plants and their beneficial role.

A challenge in developing and using ecological indicators (eco-indicators) is selecting the most effective indicators or agents in characterising the systems of interest. Eco-indicators agent can be produced or derived from important plant traits, species richness indices, landscape metrics and patterns. Plants as an eco-indicators agent have long been used to detect changes in nature. The current trend, plants are used to assess the state of the environment condition, as early-warning signals or barometers for climate changes and trends in ecological resources. Integration of eco-indicators system and landscape ecology remains challenging and promising as yet landscape ecology focuses on the reciprocal interactions between spatial pattern and ecological processes, and it is well integrated with ecology which will enhance understanding of landscape function, concepts, and develop a more mechanistic understanding of the relationships between plants, pattern and message or indicators. This application is interchangeable due to human activities towards environmental impact and also can be further manipulated

as landscape state monitoring or assessment to measure a characteristic of the structure, composition and function of a man-made or natural systems that involved the population of communities, landscape pattern, landscape disturbance process or others landscape parameters.

References

Aksorn, E., & Visoottiviseth, P. (2004). Selection of suitable emergent plants for removal of arsenic from arsenic contaminated water. Sci Asia, 30(2), 105-113.

Alam, S., Ahmad, I., Zia-Ud-Din, & Bangash, F. K. (2008). Variations of contaminants in the road side agricultural soil of Thana Malakand Agency. Journal of the Chemical Society of Pakistan, 30(6), 800-804.

Allgeier, S., Alspach, B., & Vickers, J. (2005). Membrane filtration guidance manual. United States Environmental Protection Agency, US.

Azad, A. K., Jensen, K. R, and Lin, C. K. (2009). Coastal aquaculture development in Bangladesh : unsustainable and sustainable experiences. Environmental Management, 44, 800–809.

Bernhard, A. Z., CheFauziah, I., Mike, J. M., and Gill, C. (2004). Heavy metals in soils and crops in Southeast Asia. 1. Peninsular Malaysia. Environmental Geochemistry and Health, 26, 343–357.

Ensley, B. (2000). Rational for Use of Phytoremediation. Eds. I Raskin and BD Ensley: John Wiley & Sons, Toronto.

Evans, M. G., and Furlong, C. J. (2003). Environmental biotechnology, theory and application.Chichester, England, John Wiley & Sons, Ltd.

Ghosh, M., & Singh, S. (2005). A review on phytoremediation of heavy metals and utilization of it's by products. Asian J Energy Environ, 6(4), 18.

Gosavi, K., Sammut, J., Giffor, S., and Jankowski, J. (2004). Macroalgalbiomonitors of trace metal contamination in acid sulfate soil aquaculture ponds. Science of the Total Environment, 324, 25–39.

Gräslund, S., Holmström, K., and Wahlström, A. (2003). A field survey of chemicals and biological products used in shrimp farming.Marine Pollut. Bull, 46, 81–90.

Islam, M. S., and Wahab, M. A. (2005). A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture. Hydrobiologia, 542,165–190.

Ismail, Z., & Beddri, A. (2009). Potential of water hyacinth as a removal agent for heavy metals from petroleum refinery effluents. Water, air, and soil pollution, 199(1-4), 57-65.

Jackson, L., Kurtz, J., & Fisher, W. (2000). Evaluation Guidelines for Ecological Indicators (US Environmental Protection Agency, Office of Research and Development, Research Triangle Park NC): EPA/620/R-99/005. 107.

Lacerda, L. D., Santos, J. A., and Madrid, R. M. (2006a). Copper emission factor from intensive shrimp aquaculture. Mar Pollut Bull, 52, 1823–1826.

Lacerda, L. D., Soares, T. M., Costa, B. G. B., and Godoy, M. D. P. (2011). Mercury emission factors from intensive shrimp aquaculture and their relative importance to the Jaguaribe River estuary, NE Brazil.Bull Environ ContamToxicol, 87, 657–661.

Latiff, M., Hanie, N., Shaharuddin, R. I., Muhamad, W., Asiah, W. N., & Othman, R. (2012). Study on aquatic plant species (Salvinia natans, Neptunia oleracea and Hydrilla verticillata) as phytoindicator for nutrient excess.

Lawton, J. H. and Gaston, K. J. (2001). Indicator species. In Encyclopedia of Biodiversity, ed. S Levin, 3: 437-50. San Diego: Academic.

Martin, J. L. (2011). Shrimp aquaculture: from extensive to intensive rearing, the relationship with the environment and the key to sustainability, In H.-J. Ceccaldi et al. (eds.), Global Change: Mankind-Marine Environment Interactions, (pp 25-30).France:Proceedings of the 13th French–Japanese Oceanography Symposium.

McDonald, M. E. (2004). Application of Ecological Indicators. Annual Review of Ecology, Evolution, and Systematics 35 : 89-111.

Millar, A. (2009). Macroalgae.Primefacts, Profitable & Sustainable Primary Industries, 2-5.

Miretzky, P., Saralegui, A., & Cirelli, A. F. (2004). Aquatic macrophytes potential for the simultaneous removal of heavy metals (Buenos Aires, Argentina). Chemosphere, 57(8), 997-1005.

Mishra, V. K., Upadhyaya, A. R., Pandey, S. K., & Tripathi, B. (2008). Heavy metal pollution induced due to coal mining effluent on surrounding aquatic ecosystem and its management through naturally occurring aquatic macrophytes. Bioresource technology, 99(5), 930-936.

Mitra, A., and Bhattacharyya, D. P. (2003). Environmental issues of shrimp farming in mangrove ecosystems. J Ind Ocean Stud, 11, 120–129.

Mortberg, U. &Wallentinus, H. G. (2000). Red Listed Forest Bird Species In An Urban Environment - Assessment of Green Space Corridors. Landscape and Urban Planning Vol. 50, Issues 4, Pp 215-226.

Niemeijer, D. (2002). Developing indicators for environmental policy: data-driven and theory-driven approaches examined by example. Environ. Sci. Pol. 5: 91-103.

Niemi, G. J. and McDonald, M. E. (2004). Application of Ecological Indicators. Annual Review of Ecology, Evolution, and Systematics. 35: 89-111.

Niemi, G. J. and Noss, R. F. (1990). Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. 4: 355-364.

Nora'aini, A., Nurbaiti, A.H., Ahmad, J. (2011). The potential of a polysulfone (PSF) nanofiltration membrane as the end stage treatment technology of aquaculture wastewater. Desalination and Water Treatment, 32, 242–247.

Norton, S. B., Rodier, D. J., van der Schalie, W. H., Wood, W. P., Slimak, M. W., & Gentile, J. H. (1992). A framework for ecological risk assessment at the EPA. Environmental Toxicology and Chemistry, 11(12), 1663-1672.

Nriagu, J. O. (1979). Global inventory of natural and anthropogenic emissions of trace metals to the atmosphere.

O' Connell, T. J., Jackson, L. E., & Brooks, R. P. (2000). Bird Guilds As Indicators of Ecological Condition In The Central Appalachians. Ecological Applications, 10(6), 1706-1721.

Ong, J. E. (1995). The ecology of mangrove conservation and management.Hydrobiologia, 295, 341–343.
Onwughara, N., Umeobika, U., Obianuko, P., & Iloamaeke, I. (2011). Emphasis on Effects of Storm Runoff in Mobilizing the Heavy Metals from Leachate on Waste Deposit to Contaminate Nigerian Waters: Improved Water Quality Standards. International Journal of Environmental Science and Development, 2(1), 55-63.
Philips, M. J., Beveridge, M. C. M., and Clarke, R.M. (1991). Impact of aquaculture on water resources. In D. E. Brune, and L. R. Tomasson (Eds.), Aquaculture and Water Quality Advances in World Aquaculture (pp. 568-591). Baton Rouge, Louisiana.
Phillips, D. J. (1977). The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments—a review. Environmental Pollution (1970), 13(4), 281-317.
Pinto, C., Caçonia, A., & Souza, M. (1987). Utilization of water hyacinth for removal and recovery of silver from industrial wastewater. Water Science & Technology, 19(10), 89-101.
Prasad, M. N. V., (2012). Foreword. In N. A. Anjum, M. E. Pereira, I.Ahmad, C. Duarte, S. Umar, and N. A. Khan (Eds.), Phytotechnologies: Remediation of Environmental Contaminants (pp iv). United State of America: CRC Press.
Prasad, M. N. V., and Freitas, H. (2003). Metal hyperaccumulation in plants: Biodiversity prospecting for phytoremediation technology. Electronic Journal of Biotechnology, 6, 275- 321.
Prasad, M. N. V., Malec, P., Waloszek, A., Bojko, M. and Strzałka, K. (2005). Physiological responses of Lemna trisulca L. (duckweed) to cadmium and copper bioaccumulation. Plant Science 161:881-889.
Qian, J.-H., Zayed, A., Zhu, Y.-L., Yu, M., & Terry, N. (1999). Phytoaccumulation of trace elements by wetland plants: III. Uptake and accumulation of ten trace elements by twelve plant species. Journal of Environmental Quality, 28(5), 1448-1455.
Quan, C., and Turner, C. (2009). Extraction of astaxanthin from shrimp waste using pressurized hot ethanol. Chromatographia, 70(1/2), 247-251.
Rahman, M. A, Hasegawa, H. (2011). Aquatic arsenic: phytoremediation using floating macrophytes. Chemosphere. 83, 633–646.
Rahman, M. A., Hasegawa, H., Ueda, K., Maki, T., & Rahman, M. M. (2008). Influence of phosphate and iron ions in selective uptake of arsenic species by water fern (< i> Salvinia natans</i> L.). Chemical Engineering Journal, 145(2), 179-184.
Rao, D. G., Senthilkumar, R., Byrne, J. A., & Feroz, S. (2012). Wastewater treatment: advanced processes and technologies: CRC Press.
Razanah Ramya (2015). Study on mangrove species as phytoindicator for inorganic contaminants and assessment of Zn, Fe and Cu bioaccumulation rate through in vivo model system using Lemna minor and Salvinia natans. IIUM Thesis.
River Science (2010).Macrophytes and macroalgae in the Swan- Canning estuary,Science supporting estuary management, 20, 1-12.
Rodrigues, A. J., Odero, M. O., Hayombe, P. O., Akuno, W., Kerich, D., & Maobe, I. (2014). Converting Water Hyacinth to Briquettes: A Beach Community Based Approach. International Journal of Sciences: Basic and Applied Research (IJSBAR), 15(1), 358-378.

Rodriguez, L., Lopez-Bellido, F., Carnicer, A., Recreo, F., Tallos, A., & Monteagudo, J. (2005). Mercury recovery from soils by phytoremediation Environmental Chemistry (pp. 197-204): Springer.
Senarath, U., and Visvanathan, C. (2001). Environmental issues in brackish water shrimp aquaculture in Sri Lanka.Environmental Management, 27(3), 335–348.
Shaharuddin, R. I. (2014). Potential of aquatic plant species as phytoindicators for heavy metal contaminants. IIUM Thesis.
Shaw, J. (1989). Heavy metal tolerance in plants: evolutionary aspects: CRC Press.
Shukla, R. S. and Chandel, P. S. (2006). A Textbook of Plant Ecology, Including Ethnobotany and Soil Science, New Delh: S.Chand.
Singh, D., Tiwari, A., & Gupta, R. (2012). Phytoremediation of lead from wastewater using aquatic plants. J Agric Technol, 8(1), 1-11.
Singh, S. N., & Tripathi, R. D. (2007). Environmental bioremediation technologies: Springer.
Singkran, N., and Sudara, S. (2005). Effects of changing environments of mangrove creeks on fish communities at Trat Bay, Thailand.Environmental Management, 35(1), 45-55.
Tangahu, B. V., Sheikh Abdullah, S. R., Basri, H., Idris, M., Anuar, N., & Mukhlisin, M. (2011). A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. International Journal of Chemical Engineering, 2011.
Trapp, S., & Karlson, U. (2001). Aspects of phytoremediation of organic pollutants. Journal of Soils and Sediments, 1(1), 37-43.
US EPA, (2000). Generation Resource Integrated Database (eGRID2007, Version 1.1). US Environmental Protection Agency.
VahdatiRaad, L., & Khara, H. (2012). Heavy metals phytoremediation by aquatic plants (Hyrocotyle ranocloides, Ceratophyllum demersum) of Anzali lagoon. International Journal of MArine Science and Engineering, 2(4), 249-254.
Vamerali, T., Bandiera, M., & Mosca, G. (2010). Field crops for phytoremediation of metal-contaminated land. A review. Environmental Chemistry Letters, 8(1), 1-17.
Van Ginneken, L., Meers, E., Guisson, R., Ruttens, A., Elst, K., Tack, F. M., . . . Dejonghe, W. (2007). Phytoremediation for heavy metal-contaminated soils combined with bioenergy production. Journal of Environmental Engineering and Landscape Management, 15(4), 227-236.
Vanek, T. and Schwitzguebel, J. P. (2003). Phytoremediation Inventory - COST Action 837 view. UOCHB A VCR, Czech Republic.