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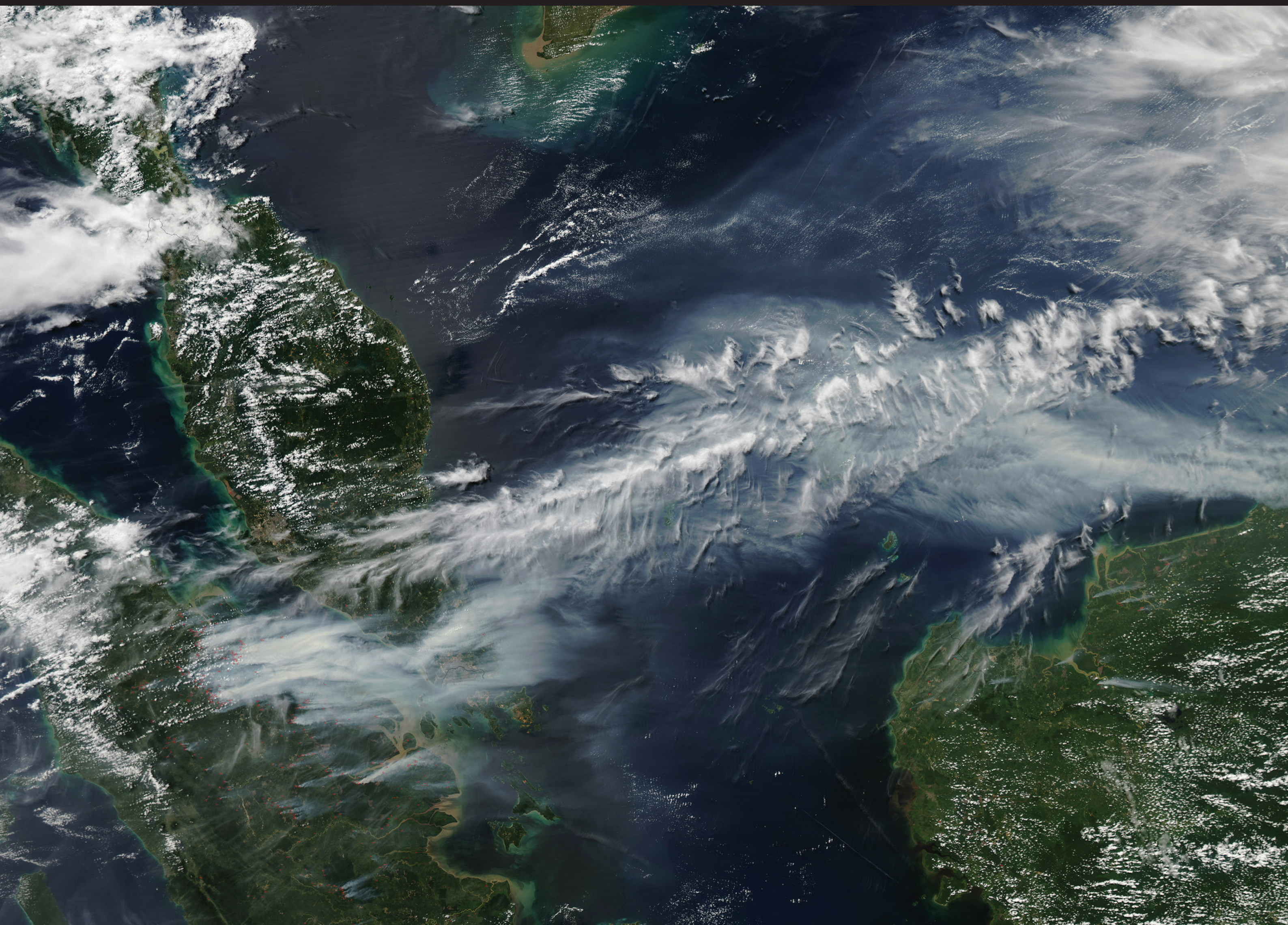

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Contents

Planning for Desirable Land Uses in Periurban Landscapes: Application of a Spatial Concept for Territorial Sustainability

Domenec Aran Guiu[1]

Abstract

With the aim to test the categorical formulation of a spatial concept on the functional, desirable characteristics of land-use distributions inside periurban landscapes, in the research we envisaged and developed an original quantitative method, deployed in nine study-cases worldwide.

Increasingly facing a generic set of pressures from suburbanization and unregulated land-use change, unwanted spatial outcomes in those landscapes often arise after trespassing critical thresholds of ecosystems' processes inadvertently: Overriding the minimum-area requirements, for example, of crucial ecosystems providing basic ecological services to whole urban regions.

Spatial concepts can be powerful tools for strategic planning of territorial systems, helping to avoid shortsighted plans and policies. From the narrative of a spatial concept supportive of strategic planning and regulatory policies for territorial sustainability (the "Aggregates-with-Outliers" -AWO), we developed an original synthetic, quantitative method fostering statistical analysis between diverse locales, years, and scales -as well desirable scenarios.

From the joint maximization of size variance and land-use diversity (JMV+D model), we evidenced deficits and potentials on the composition of heterogeneous periurban landscapes, from the universal perspective of the concept. It is considered a tool (among the many required) for the strategic planning of territorial sustainability in those landscapes, especially required of a flexible definition on the desirable spatial outcomes of plans and policies.

Keywords: Territorial Sustainability, Spatial concepts, Landscape analysis, Mosaic heterogeneity

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1. Introduction

Stating the case for applicability of normative spatial concepts in strategic planning, in the study we tested a spatial concept (*Aggregates-with-Outliers*-AWO; Forman 1995) that defines desirable land-use distributions in periurban landscapes -the ones at the fringe of metropolitan areas or urban regions.

Spatial concepts are tools which often seek optimization of functional processes by integration of landscape components. Some rely (to different extent) on the non-linear dynamics paradigm, as the referent on the complexity of territorial systems: In the AWO case, with the explicit aim to improve territorial sustainability and resilience of the landscape (as a coupled natural-human system) in an applied way.

Following this goal, we focused on the question whether this particular concept could be developed and applied as a technically-relevant tool for strategic planning; eventually becoming a universal reference for the functional analysis of the fast-changing, old cultural landscapes of the metropolis. Through the comparative analysis of historic-agricultural landscapes located inside urban regions or megalopolis (Barcelona region in Spain; North-East megalopolis of US; Beijing megalopolis and Anhui-Nanjing region in China), the research contributes this way to the definition and implementation of integrative approaches on territorial planning.

These landscapes experience indeed similar strong urbanization pressures, and increasingly have problems with the provision of natural ecosystems' services. Those global trends take place across different continents and bioclimatic regions, yet within specific physical contexts and diverse socio-economic, cultural, and political background or traditions. From this perspective, differences on socio-economic characteristics, cultural or political structure are shaping in a good part the specific land-distributions to account for, in a comparative analysis; in part the product of a local situation, and the physical context in which they are embedded. This is a territorial complexity playing at multiple scales too: From the ecosystem to the landscape, and the biosphere.

The specific coevolutive patterns resulting from human and natural subsystems' integration are still reflected, nowadays, on the land-use structure of vernacular landscapes; where human adaptations (out of poverty and necessity) were cultural investments in nature. Yet nowadays we see, instead, a globalization process that homogenizes human impacts, and provides standard solutions on land uses; increasingly alienated from nature, and affected by not-retrofitting the actual impacts on the environment. As a consequence, humans are greatly affected by the decrease on the amount and quality of the "taken-for-granted" ecosystem services (as clean water, clean air, fertile and productive agricultural soils, or clean food).

To place the problem in context, for the first time in history there are now more humans dwelling in urban areas than not, increasingly in a characteristic low-density suburban sprawl which already comprises over fifty-percent of the total area available in some countries (since year 2000 in US); quickly becoming a universal-trend or 'urban tsunami' (Forman 2008: 253). This is the urban fringe where the rural-urban dichotomy becomes messy, often a mix of non-structured and waste spaces. Hence, strategic planning should focus on those not-yet urban landscapes with unresolved structures, in order to avoid wasteful consumption of space (inside a seemingly disposable landscape).

Besides, periurban landscapes often retain agricultural land which is critical for whole urban regions, both in decreasing the ecological footprint and for maintaining the strategic supply of ecosystem services, food and materials: Increasing resilience this way against global alterations, while diminishing risk spreading (from economic fluctuations and climate change, eg.).

Regarding the impacts over environmental systems, and the question of how fast biodiversity is disappearing, no precise estimates are available -neither on the number of species lost, or the range. We do know that the current decline of biodiversity is occurring 1,000 to 10,000 times faster than at any other time in geological history, and that over the last 50 years humans have modified those ecosystems more rapidly and extensively than in any comparable historic period (Millennium Ecosystem Assessment 2005).

We know as well that biodiversity reduction is a function of territorial size and isolation, and that a ten-fold increase in area results in a doubling of species. This leads to the concept of interrelation of species and area (Wilson & Peter 1988), and the definition of compositional thresholds for interrelated ecological, socio-economic processes (for example, the threshold in suitable land uses, and species movement of percolation theory; see Farina 2000 eg.). If we know human settlement and activities are the main drivers of land-use change and natural impacts, striving for the remedial planning (and positive actions required) becomes the more compelling, therefore.

As a proactive tool for strategic planning, remedial proposals usually integrate socio-economic and historical factors in order to explain actual and desirable mosaic-pattern configurations. This balance can be framed, for instance, as a dynamic multifunctional equilibrium; not least, in order to cope with the rising tension between providing human and ecological services, and the required flexibility of planned development (Alberti & Marzluff 2004).

Eventually, with properly-integrated approaches we will consider, in a synthetic way, the most significant components of spatial complexity inside existing cultural landscapes, from their definition as coupled territorial systems. This includes its main environmental and socio-economic aspects, social values and the cultural meaning attached to different spaces. Even when considering the spatial concepts as ‘thought experiments’ (theorizing on the optimal distribution of land uses in the landscape eg.), its development may contribute to the quest for a dynamic balance between the provision of ecosystem services and the amount of desirable, regulated land development.

For such integrative (holistic) purpose, we are told consistency inside a diversity of methodological approaches is especially required, starting with data collection: As roadmap, we should design studies allowing contrasts to emerge from comparison of data, guided by a conceptual framework that accounts for interactions at multiple scales (O’Sullivan 2004; Carpenter et al. 2009).

Our approach, then, was defined in line with applied efforts to characterize and quantify, in a consistent and systematic way, the actual situation and diversity of such compromised landscapes worldwide. For this, we aimed to test the applicability of a spatial concept from Landscape ecology, elaborating on the adequacy of normative concepts for strategic planning in general. Our sequence started by testing the conceptual strength of the spatial concept. Once validated, we would inquire on the feasibility of its deployment; eventually allowing at the end (as a development) the functional definition of the desirable landscape characteristics, and a comparative analysis on mosaic distributions from a universal perspective.

This would be a quantitative approach that measures the spatial blueprint of territorial complexity and human activity in periurban landscapes, as reflected by our original synthesis on composition and heterogeneity of land uses. It may become, therefore, a suitable tool for the territorial macro-diagnostic of the study units, and the evaluation of the policies implemented.

2. Conceptual Framework

2.1. Spatial concepts: Problem-solving strategies in landscape planning

The AWO concept was originally formulated to address, in a synthetic way, the spatial optimization of periurban landscapes, combining both natural and human subsystems (Forman 1995). As any normative statement, it has to be analyzed mainly at conceptual level: Eventually its applied, technical relevance derives from a sound theoretical framework, and effective formulation.

In contrast to descriptive empirical approaches, by definition spatial concepts are strategies used to build systemic solutions to complex problems (Ahern 2005). Partly intuitive problem-solving tools for planning, spatial concepts usually start by addressing a perceived lack or malfunction in territorial systems. In this sense, they can be regarded as extensions of thought-experiments, where a multiplicity of competing accounts of the same setting is possible. The context and intent of each concept's narrative become important elements on the evaluation.

For instance, when we ask -from a similar problem-solving stance: "Why are societies no-longer able to produce landscapes of ecological and aesthetic integrity?", we invariably return to historical concerns arising from a perceived malfunction of human subsystems, since the Industrial Revolution at least: The failure to design new urban patterns coherent with history and context, inside pre-existing cultural landscapes.

Either perception or evidence on failed integration of human and natural systems, it was nonetheless in reaction to this perceived loss (or "uglyfication") that landscape tourism emerged during the first half of the 19th century in New England, and other industrialized regions. Nowadays, and perhaps going full circle, tourism and recreation play a determinant -yet ambivalent- role, on the remaining agricultural landscapes of the urban regions or megalopolis.

Hence, in terms of meaning landscape-planning strategies are quite related to social perception (Walker 2005: 84). On the other side of the same coin, for successful planning we are required to shape existing community values and perceptions (Gunder 2005). Far from objective, we must clarify the purpose of our intended optimization processes (eventually, a questionable goal in itself).

How then can we define the problem and the required methods, in order to validate our spatial intuitions regarding the perceived loss of cultural landscapes, and its territorial effects? Probably this can only be answered by holistic, synthetic spatial approaches that integrate social and environmental subsystems, at the same time than identify the spatial dimension as key factor for the analysis of elements' interactions.

Following such methodological approach, after some analysis our "informed intuitions" may be quantifiable -when based on sound conceptual formulations. For instance, we can define our quest as a statistically-comparable, mensurative experiment (*sensu* McGarigal & Cushman 2002) concerning the functionally-desirable outcome of a landscape mosaic -as an integrated territorial system, composed by coupled human-natural subsystems.

2.2. Spatial optimization in cultural landscapes

From dynamic systems' theory and resilience thought, we are told the key to preservation of existing cultural landscape integrity and identity (fostering place-making) arises, as a whole, from enhancing resilience of socio-ecological systems: Rather than optimizing efficiency of some isolated component, we need to foster adaptability of the whole system to internal and external change. This implies allowing for the necessary innovation to take place, inside an inherently creative cultural process (Walker and Salt 2006).

In this sense and considering historical precedents, we can question whether the traditional approaches of East-Asian societies were more integrative (and aesthetically successful) than currently-engineered approaches.

It may be the case for example of the traditional Chinese Feng-Shui landscape, where the fractality of territorial systems (disposed as 'boxes-within-boxes') provided the 'live-within' integrative context for inhabitants — the equivalent of a phenomenological process of dwelling (Yu 1994: 330): An integrated hierarchical vision which fostered the psychological requirements of place-identity. At the dwelling-scale for example, and in order to reflect the cultural character, designs symbolized and had a meaning attached to family expectations; fitting the house into its social and historical background, and providing the symbolism shared by its dwellers (Xu 1998).

The traditional disposition of Korean nested-villages inside "woman valleys" (defining the *Tong* or "same people" communities) would be another such case. Similar integrative views were present in the multifunctional Satoyama landscapes in Japan (lit.:"village-mountain"), which combined intensive-rotational productivity schemes, and the maintenance of long-term ecosystem's services. This was an adaptive survival strategy which, remarkably, resulted in a higher natural diversity too (Yokohari et al. 2000; Duraiappah & Nakamura 2012): A good example that human activity can be a positive agent shaping natural systems, and not always pernicious.

Although in Western context the urban and the rural are traditionally seen in dichotomy, we can find as well some precedents of integrative planning and design. Inside the regions of study for example, mid-19th century pioneer, urbanist Ildefons Cerda envisaged and deployed a plan aiming for the spatial optimization of Barcelona expansion. Arising from his egalitarian Social philosophy, he had as declared goal improving urban population's living conditions while fostering place-making (Cerda, 1867). With the aim to urbanize the rural and *ruralize* the urban, the balanced outcome of his equation is still considered a reference on city spatial-optimization -even if from a characteristic 19th-Century positivistic approach (Pallares et al. 2011).

As a more recent -yet equally pioneering- approach, the integrative goal of Ian McHarg's (1969) regulatory planning model (or *ecosophy*) was essentially a multi-layered planning sequence, which advanced the current view of natural system's processes as social values in themselves (like ecosystem services): Land, air and water resources are indispensable to life; and recognition of those as social values will, in turn, define the character of a given place. Inferences can be drawn then regarding land utilization in order to ensure optimal use, with the enhancement of the social values that constitute its intrinsic suitability: Each place is inherently suitable for a multiplicity of human uses, and it remains within society to make the choices, therefore.

In parallel, from system's theory and biology, the concept of resilience has become a key issue for the definition of sustainable territorial strategies nowadays. In Panarchy theory for instance, the systems' non-linear, alternating stable-states create normal journeys (or constantly-evolving outcomes) that maintain the diversity of components, spatial patterns and genetic attributes: This composes the basis of ecological resilience, counter to the engineering resilience concept (Holling 2001).

Still, we keep implementing models that seek incremental growth and efficiency optimization in a linear way, for a single productivity variable (the "business as usual" option). Yet, such optimization does not work when applied as a best-practice model in reality, since long-term response to shocks and disturbances depends on the context, the connections across scales, and the current state of the system (Walker and Salt 2006).

Efficiency by itself may not be the problem; however, when applied to a narrow range of values, and a particular set of interests eventually sets the system in a long-term trajectory that, due to its complex nature, leads to highly-unwanted outcomes. If we acknowledge reiterated evidence over long periods in conservation programs, it may well follow the era of ecosystem's management via increases in efficiency is over (Peterson 2002).

Almost in opposition to the traditional paradigm, from non-linear system dynamics we are told that heterogeneous, unique ecosystems arise from concatenations of beneficial processes striving to achieve coherence, selection and centripetality (generalized autocatalysis or self-organization), against the ineluctable tendency of structure to decay following the second-law of thermodynamics (Ulanowicz 2009).

Thus, landscapes may self-organize in a similar way than other systems that contain life. This fact could be detected when looking to the complex spatial patterns of ongoing processes (Cumming 2011). Not surprisingly, in coupled socio-environmental systems, social values play an important role in the maintenance of current spatial patterns (same time than affected by). Or as M. Castells remarked (1983), space is not just a reflection of society, it *is* society. The paradox of efficiency and spatial optimization includes the fact that, with a given increase in efficiency, it results in major inefficiencies in the way we generate values for society (Walker & Salt 2006).

Is this social dimension's (ambivalent) role so difficult to detect? If quantifiable, the interactive effects of community values and landscape spatial distribution would be clarified, fulfilling communities' quality-of-life standards, and attached place making.

Further questions on social values and attached meaning refer for example to the role of recreation and tourism, increasingly important parts of the territorial equation. Similarly, the characterization and quantification of the impacts of new drivers of change, and its dynamics, may provide a useful complementary view: Those are presumably modular (with breaks) at multiple scales. Equally, measuring the spatial implications of the new global context may be relevant, in relation to ongoing cultural change (as a footprint, for instance).

In the study and following from the analysis of functional typologies of patches, we considered this way whether collective values and related human activities could be comparatively discerned at all, from any particular arrangement of actual landscape mosaics, and its inherent spatial heterogeneity.

Operatively, to foster adaptability of whole systems to dynamic change will require more than incrementally-optimizing a single-productivity variable. Yet, deploying whole arrays of indexes in purely-exploratory approaches probably will tell us nothing relevant, either about the subjacent factors of overlapping indexes, and the frameworks required for interpretation. Which kind of guidance for positive action should we expect, when lacking a putative, mechanistic explanation of the results?

Alternatively, a methodological approach would be to consider the joint optimization of critical-heterogeneity variables -the known spatial-keys fostering resilience to the whole territorial systems. This implies, on the one hand, a normative statement on such crucial aspects affecting the range of the desirable spatial distributions to be achieved. Operatively, it implies a convergence towards a broadly-optimal, or desirable range of values for the critical variables involved, rather than optimizing a single variable.

2.3. Developing on the Aggregates-with-Outliers *concept*

As one of the many spatial concepts arising from Landscape ecology, the AWO concept defines seven guidelines for strategic planning. It does so while trying to answer the apparently-ingenuous, yet provocative question: 'Which is the optimum spatial distribution of land uses in the landscape?'(Forman 1995; table 1).

Derived from the conceptual Patch-Corridor-Matrix spatial model (Forman & Godron 1986), the AWO concept is part of a "Spatial Solution" that states, in a normative way, there are universal land-use configurations that respect most ecological conditions, allow for a range of human uses, and permit the conservation of the greatest part of natural processes (Forman & Collinge 1996).

Table 1. Normative criteria of the Aggregates-with-Outliers spatial concept (Forman 1995).

Aggregates-with-Outliers
1. Existence of large Aggregates of natural vegetation
2. Variance on grain size
3. More than one big block of natural vegetation or agricultural use
4. Existence of small patches ("Outliers")
5. Small patches located along large patches' borders
6. Small blocks of natural vegetation
7. Corridors

The soundness of the AWO normative concept for strategic planning is stated in the literature (eg. Ahern 2005, Wu 2008). At the basis of the normative definition, seven criteria are defined as qualitative guidelines for the improvement of functional characteristics on territorial sustainability of periurban areas; ones which arise from a desirable combination of specific typologies of spaces, inside the heterogeneous mosaics.

The quantification models to develop and apply should direct then the analysis of actual mosaic configurations to the conceptually-desirable optimal situation, as stated in AWO terms. For this, the definition of internally-homogeneous spaces, and its diversity is a central aspect: Nonetheless, it is from compositional analysis on internal diversity, than system's relational aspects emerge (Gustafson 1998).

At the end, our main interest in performing a compositional analysis of the landscape in AWO base derives from the statement of a few functional, qualitative criteria of universal value by the spatial concept. Eventually, once the functional typologies of spaces and related thresholds identified in actual datasets, the quantification of landscape mosaics could follow. Following from this original development, our mensurative experiment may also provide the mechanistic approach avoiding an enumeration of values by indexes of form and structure; or empirical analyses without an integral conceptualization of natural and human subsystems.

The aim here would be to provide a more coherent, synthetic interpretation on the configuration of the heterogeneous landscapes. Yet, before any development, it has to be proved the validity of the concept from an applied modeling perspective; this is, has to be considered technically and functionally relevant, demonstrating instrumental capacities for applied analysis (and strategic planning) of the actual landscape.

2.4. Synthetic approach to the analysis of landscape pattern

In practice, it is to expect that conceptually-vague or ill-defined questions may arise, following from the deployment of any theoretical formulation into reality. In our study, issues arise mainly reflecting the inherent difficulty of applying abstract spatial concepts to existing territories: For instance, they will appear the moment we treat an ecosystem (definable as a set of processes) as a closed, spatially-bounded biotic unit. Adding to this, although human alteration and impacts are pervasive, usually is not defined as part of ecosystems' processes.

Similarly, to face the wide-ranging consequences of the "urban tsunami" over the fast-changing territories, also implies questioning and redefining the (often implicit) social values at community level. The redesign of daily-life landscapes (the "place") at the scale of the functional region or mega-region (the relevant context for analysis of cultural landscapes nowadays) would be the objective here. Among other issues, this is why we are required to work with coupled socio-environmental systems and processes, in order to attain the necessary integration, at the system domain, of the landscape and region.

In line with integrative goals of systemic approaches, for attaining such redefinition we are required to foster some sort of ecological resilience inside territorial systems (self-organized flexibility and redundancy), increasing system's innovation and adaptability, therefore. This implies questioning optimization solutions which, by defect, limit the range of available options to the narrower engineering-resilience concept.

We should look instead at the partitioning of diversity, the non-random phenomena associated with discontinuous structure, or the key clumps, discontinuities and thresholds generating modularity and resilience. Options include checking the actual situation of ecosystems against the compositional thresholds defined in studies (table 2).

Table 2. Proposed thresholds in ecosystem management and conservation. *Fonts (eg.): Stauffer & Aharony 1994, Gardner et al. 1987; Harris 1984, Holling 1992; Svancara et al. 2005; Roth et al. 1996; Alberti & Marzluff 2004.*

Percolation thresholds	*Old growth forest*	*Higher bird diversity*	*Fish comm. Health*	*Impervious watershed*
40% habitat reduction, configuration disconnected	100ha large patches are required	Large patches 100ha, over 30% total land	50% land in watershed as agricultural	Max. 10-15% urbanized of total area

Nonetheless, to increase the resilience of landscape's spatial pattern we can generate novel conceptual and methodological approaches. For example, the use of "Open historicity" conceptual frameworks allows us allocating a given landscape mosaic inside a continuum of spatially-dynamic patterns (by the "temporal convening of the spatial"; Massey 1999: 262). In a similar way, both the ideal AWO distribution and the actual mosaics can be defined along a contemporary axis on entropy, or spatial heterogeneity degree (figure 1).

It is also possible to define them as "territorial narratives" hinting at mosaic distributions, at a given place and time. Those de-contextualization schemes would be, anyway, part of the required collection of heterogeneous experiments on landscape pattern (O'Sullivan 2004; Carpenter et al 2009).

In sum, we can develop specific methods and tools for strategic planning when looking to formulate (as in our study) the desirable, synthetic landscape-pattern for a given area; same regarding design of mensurative experiments: As long as we are aware they are part of a narrative, that spatial heterogeneity may interact non-linearly with the existing drivers of land-use change, and there is no optimal land-architecture that works for everything (Turner 2010), we will be contributing to find the effective means to deal with territorial complexity in those increasingly-altered landscapes, from an existing knowledge base.

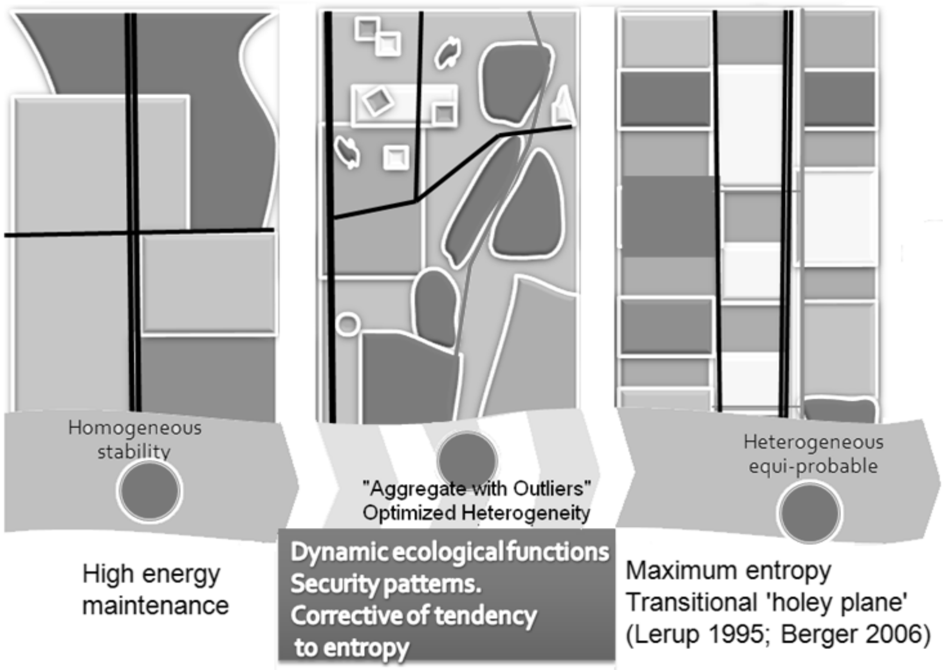


Figure 1. Diagram of heterogeneity gradient (aggregated land uses) in the landscape: Homogeneous AWO heterogeneity Heterogeneous sprawl

3. Materials and methods

3.1. Structure of the methodology

For the applied, strategic planning of territorial systems we know some basic characteristics to be fulfilled by the integrated problem-solving approaches, avoiding methodological *ad-hoc* solutions: Implying, at the end, a conceptual framework that accounts for interactions between components at multiple scales (O'Sullivan 2004; Carpenter et al. 2009); cementing our search for evidences of subjacent systemic processes that may emerge, while considering each case as unique. In the first place then, we need to redesign studies for comparability, shifting between scientific-reasoning approaches when required to gain insight. In so doing, we will widen our analytical frameworks, and promote the epistemological dialog inside holistic approaches (Rhoads 1999).

In this sense, the paradigm of complex living-systems in Biological Sciences appears as especially suited for systemic, holistic approaches. It implies, nonetheless, a leap from the deterministic mechanicism that still defines most of the lineal (partial) approaches to system's efficiency and optimization (both in natural and human subsystems); and landing instead at the emerging paradigm of non-lineal systems' dynamics, with an emphasis on living systems' processes and interrelations, and the optimization of ecological resilience.

One of the main implications of the shift in emphasis on ecological resilience, is the in consideration of the functionality of marginal elements (eg. habitats) in a system –a "Copernican shift" maybe: The "outliers", instead of the marginal, redundant (thus inefficient) elements in a system awaiting efficient planners and managers to do their job, are the main providers of flexibility, innovation capacity, and resilience to the whole system, in case of alteration.

The consideration of the landscape or region similarly undergoes a shift in perspective, stated ultimately as a main research question: Are these territorial systems a passive reflection of external agents; or are in fact "self-organizing complex systems" (SOCs), in analogy to living systems' theory?

This was a subjacent question framing the present study, and its development. In particular, we implemented an analytical sequence which considered, in parallel, the feasibility to develop such kind of spatial analysis. In so doing an unexpected, original development emerged along the process -as debated in the discussion. For instance, initially and in line with analytical goals, the sequence implied:

1. Checking the strength of the conceptual formulation, the basis for further criticism and development. This amounted to validate the deductive process of analysis, and the formulation of the normative criteria: Its synthesis on spatial principles from landscape ecology, biology conservation, and related fields (Forman 1995; Ahern 2005; Wu 2008).

   It included checking the topological definition of functional patches, as implied by the spatial concept's criteria; as well the "entification" of internal spaces, and the landscape unit. This equated to testing in practice the vaguely (or implicit) spatial formulations of the concept. That is, the feasibility of its application to actual study-cases (technical relevance).

2. After stating its conceptual strength and with the clarification on preliminary topological issues, we were to check the functional relevance of the spatial concept's typologies of spaces: The value of any modeling or development depending on this particular.

   As envisaged, the measurement of landscape-mosaic heterogeneity according to AWO classification was the applied, empirical stage of the research. This involved the definition of size-thresholds differentiating typologies of spaces related to their functionality. Results were later to be checked in two ways:

   a) From usual compositional analysis: With statistics on diversity and density of elements, as well distance-decay models;

   b) How the empirical results on AWO-base compared to definitions of functional thresholds in ecological studies, both for natural and human systems (table 2).

   If functional relevance was empirically attached to the AWO spatial criteria, they would eventually satisfy the requirements for any new development (qualitative or quantitative), when based on these premises. Corresponding to the final stage of the research, it would allow implementing a mensurative experiment based on the spatial concept's formulation, even if synthetic refinements were required. We would be able to measure, then, differentials in percentage of area for the actual typologies of land uses, against the ideal ones the AWO concept states.

3. At this point, and emerging from the conceptual and empirical findings, we found it was quite feasible (almost unavoidable) to formulate a synthetic model based on just two key, jointly-optimized variables; ones which satisfy most of the spatial requirements of the AWO concept, as well ecological management studies –table 2. At the same time, allowing for the implementation of the mensurative experiment in a simplified way.

   This is then the actual development of the present research, considered an original contribution to the sustainable, strategic landscape-planning: A compositional-optimization method, which deploys the Joint Maximization of Diversity and Variance (JMD+V) at its core.

Hence, and in line with the spatial concept premises, at the end it would allow a development which may provide, on universal grounds, some of the highly-required applicability characteristics regarding the planning of desirable periurban landscapes, as arising from the integrated spatial analysis of territorial systems. Providing insight and guide, for instance, on the definition and search of the relevant spatial information and metrics required; taking into account, from the start, the functional implications of actual and desirable typologies of spaces and thresholds, in landscapes where human agency and intention are the main drivers of change: A comparative analysis eventually providing insight into coevolving, self-organizing landscape processes.

3.2. Compositional optimum method

Following from the AWO qualitative formulation then, in the study we hypothesized the functional quantification of landscapes' spatial typologies and thresholds may actually allow for an original, synthetic refinement built on universal ground. After checking the validity of the conceptual formulation and its technical relevance, we defined the "Compositional Optimum Method" (COM) as the basis of an original, applied mensurative experiment on landscape composition purely in AWO base. Progressing along the initial methodological sequence, as main output we finally were to obtain percentage differentials regarding the existing-versus-desirable land use distributions, for a given landscape (figure 2).

Here the definition of land-use typologies of homogeneous spaces ("patches") followed from the functional definition along the gradient "natural vegetation / agricultural / urban". The other compositional dimension (size-variation of patches) involved the definition of functional typologies of spaces according to size (as stated by the spatial concept), and thresholds implied.

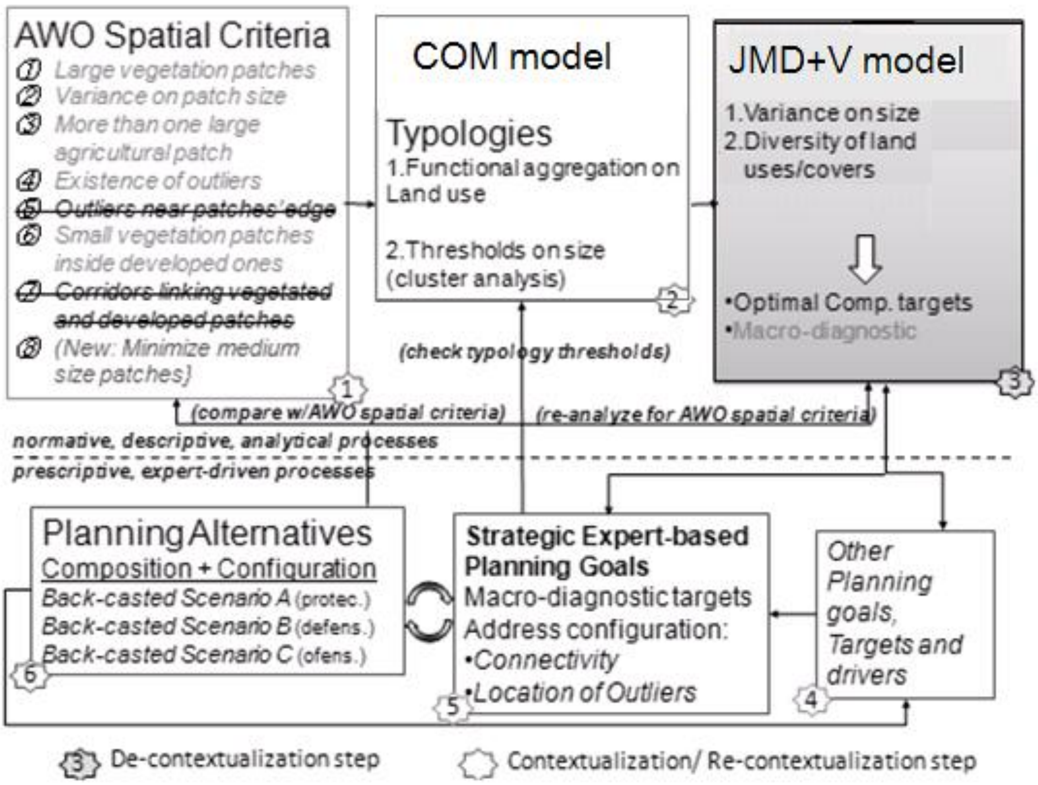


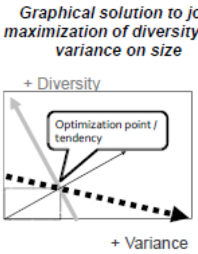
Figure 2. Conceptual diagram for application of the synthetic approach in the study.

Operatively, in order to test AWO suppositions about the existence of functional typologies of spaces by size (following from the basic differentiation between "Aggregates" and "Outliers"), from the start we treated the comprehensive analysis of landscapes' patches independently of any functional land-use aggregation. "Raw" patch-size typologies were simply defined this way through a Cluster-analysis dichotomization sequence (deploying the K-Means method on variance), giving as outcome the resulting size-aggregations and thresholds.

Besides a spatial macro-diagnostic of the landscape, the quantification of differentials against the actual situation would equally allow for the comparison between landscape distributions. Initially to be deployed as a mensurative experiment inside the Barcelona urban region, it was the first step for the characterization and diagnostic of worldwide periurban-landscapes in AWO base.

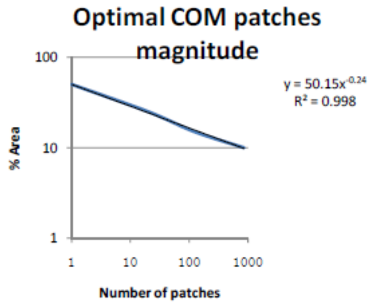
Results were expected also to (comparatively) point to thresholds of compositional values and parameters of spatial heterogeneity; ones which are instrumental for the provision of the universal ecosystem services and, eventually, may help identify related social values.

The definition of AWO functional typologies of patches would allow, at the end, a territorial macro-diagnostic on landscape pattern composition, against which different spatial patterns of the culturally-unique landscapes could be contrasted, and possible scenarios defined (figure 2).



Opposite behavior of diversity and variance

Cases	pi	pi	pi	pi
1	100	99	50	25
2	0	0	50	25
3	0	0	0	25
4	0	1	0	25
Diversity	0	0,06	0,69	1,39
Standard dev.	43	43	29	0
Variance	1875	1826	625	0



Category spaces	Proportion size	Proportion Use	Spaces use
Matrix	0,56	0,56	Agriculture
Large	0,32	0,08	Forest
		0,08	Agriculture
		0,08	Urbanized
		0,08	Transition
Medium	-	-	
Small	0,12	0.027	Forest
		0.027	Agriculture
		0.027	Urbanized
		0.027	Transition

JOINT OPTIMIZATION	Agriculture	Woodlands	Urban	Transition	Total
Matrix	~~6%~~ 25	~~6%~~ 0	~~6%~~ 0	~~6%~~ 0	~~25%~~ +26% 51%
Large	6%	6%	6%	6%	25%
Medium	~~6%~~ 3%	~~6%~~ 3%	~~6%~~ 3%	~~6%~~ 3%	~~25%~~ 12%
Small	~~6%~~ 3%	~~6%~~ 3%	~~6%~~ 3%	~~6%~~ 3%	~~25%~~ 12%
Total	~~25%~~ 65%	~~25%~~ 11'5%	~~25%~~ 11'5%	~~25%~~ 11'5%	

Figure 3. Examples of joint maximization of variance and diversity: behavior of the two variables, zero-medium patches and best fit (accumulated area) scenarios.

At this stage, we already detected main composition criteria were subjacent in configuration ones (eg. existence of corridors, or location of the "outliers" dependent on the number and area of large-patches). Hence, along the process we found our mensurative experiment was possible to be developed in an even-more synthetic way, following the universal heterogeneity requirements subjacent in the logic of the AWO concept, and applied ecological studies (eg. ones in table 2): We defined thus an original synthetic model ("*JMV+D model",* after 'Joint Maximization on size-Variance and land-use Diversity' -figure 3) that quantifies differentials against desirable situations or scenarios, from the joint maximization of key criteria on spatial heterogeneity.

3.3. Application to study cases

The applied, quantitative goal of the study was to provide evidence then on the variability (differentials, correlations) of the mosaic distribution by the JMD+V model: A procedure defined as an observational - mensurative experiment (McGarigal & Cushman 2002). In the general case, potential study cases are found within a larger filtered set -all the periurban landscapes of a given region, in our study. From their comparison, we are providing statistical evidence, in this way, on the degree (or close fit) from actual data on landscape distributions against the desirable, optimal distribution.

Use of explicit and replicable GIS analytic methods is of great help in the definition, test, and application of spatial planning concepts (starting with the measure of physical dimensions, eg.). When contextualized within existing socio-economic data (available surveys and datasets), the analysis of spatial variability and heterogeneity becomes an important support for prospective analysis in territorial planning: From that, we may attach new direction and meaning to obtained results, as well.

Geology and topography (contour levels, slopes) were the physical criteria in the study for the delimitation of the landscape units (e.g. sedimentary planes in a watershed), from which we analyzed the functionally-aggregated land-use typologies (the spatial definition of ecosystems, or ecotopes). Delimitation of study units was mostly coincident with the sub-watershed level, considered a desirable feature for the analysis of territories and its sustainability: Framing them as an integral part of the natural basins, and broader ecoregions.

Regarding the delimitation of physical boundaries, we have to work with distinctive landscapes inside watershed sub-basins; mainly characterized by hydrological processes, vegetation and topography (eg. alluvial plains, foothills, mid-mountain areas), with a repetitive land-use internal configuration. Particular configurations of topography, vegetation, land-use and settlement patterns already define some coherence of natural and cultural processes, and activities (Forman 1995; Farina, 2000; Antrop, 2001).

The nine cultural landscapes analyzed by the study are located in the Barcelona region (plains of Valles, Penedes, Vic, Bages, Conca de Barbera), the North-east megalopolis of the US (Pioneer Valley MA, Conestoga PA) and in China (Miyun in the Beijing Mountain Area, Hefei Chaohu fringe in Anhui province).

Initially, the comparison of the five Barcelona periurban landscapes defined the methodology of the mensurative experiment that was expanded later to the rest study cases worldwide. Despite the suburbanization processes already in place, Barcelona's poly-nucleated region is considered a model regarding densification and arrangement of land uses, with a comparatively lower (more efficient) land consumption (Forman 2004; 2008). It stands, then, as a general referent on the desirable periurban outcome which is coincident with the intention, objectives, and postulates of the spatial concept.

The deployment in the sub-basins of Barcelona urban region was the first test of the mensurative experiment then; providing evidence and guidance on the main spatial characteristics of the actual-versus-ideal distribution, the expected range of values for typologies, and keys for interpretation of the interrelations with the physical, social and economic context.

After this initial experiment, application to study-cases worldwide became the next step: Expanding the filtered set of landscapes, to encompass similar landscapes of all the regions of the Earth, in practice. The main interest for the selection of cases inside such large set was to expand, potentially, the range of variability or coincidence, on the periurban landscape-distributions worldwide.

The selected cases of the North-east megalopolis of US were two characteristic cultural landscapes of special interest, yet for different reasons. The Pioneer Valley in Western Massachusetts is a visually contained sub-basin, allegedly fostering a sense of inclusiveness and place-making. Artists of the Connecticut School (and the legions of landscape tourists that followed) understood the appeal of the place in its proportions, which epitomized 18th century ideas about the proper balance between the natural world and the built environment (Buckley 2004; Doezma 2002). The physical depictions of the Valley still draw attention to the small, convoluted topography of the place, as opposed to the open plains of the West (Morgan 2002).

The landscape has a much different character today nevertheless, after several waves of immigration, the decline of both factory-based industry and agriculture, and the rise of low-density suburban sprawl. Population and housing density evidence the characteristic exurban/rural densities (equal or over 160 hab./km^2).

In Lancaster County PA, the Conestoga River flows through a highly-productive pastoral landscape ("The garden spot of America"), farmed extensively by the Pennsylvania "German farmers" (which include Mennonites and Amish, as well as other groups of the Anabaptist movement). The tension between rural and urban is heightened in the landscape by the historic connection to agriculture, against the metropolitan pressures of the nearby Philadelphia, New York and the whole North East region -to which are main providers of daily produce. Remarkably enough, despite pressures Amish and other residents remain devoted to farming: This is still a sacred landscape for them, and they consider themselves stewards of the land (Peterson 2005).

The analysis was quite appealing, from a territorial sustainability perspective. Existing social and community integration at the cultural level has fostered, in this case, a resistance to the centripetal driving forces working against the traditional rural communities everywhere (Walbert 2002). Nonetheless, upon this growing internal tension new pressures have emerged: With four million tourists annually an industry has developed in last decades, which is now second only to agriculture (Kraybill 2001).

In China, the Chaohu fringe in Hefei (Anhui province) is a historical representative of the highly-engineered, water-regulated agricultural plains. East of Nanjing and Shanghai regions, nowadays is one of the fastest-growing cities in China, facing strong suburbanization. The study area was located on the north side of the lake, south of the city center. Besieged by new developments encircling the remaining agricultural areas of this traditional polder landscape, is in close vicinity to some natural preservation areas on the lakeside; home to species of migrant birds such as egrets and herons, whom locals still want to coexist with. Hence the proposed motto: "Egret city" (Li et al. 2005).

Huairou-Miyun in the Beijing North Mountain Area is considered a critical spot for ecosystems' service provision to the capital, especially water supply. Defined as its "Ecological Great Wall", effective protection of agricultural land by governmental regulations is allegedly providing a mechanism today to confront low-density suburban sprawl, helping to maintain water and food supply to the capital. Even so, as part of the Beijing megalopolis the whole basin faces the seemingly-unstoppable progression of a characteristic "scrambled city" suburbanization pattern (Yu et al. 2011).

Besides their specific cultural and political context, with the two selected periurban landscapes we wanted to look for comparative evidence of differentials in landscape-pattern inside China, as well against Western countries. This having in mind the characteristic interplay of central and local powers in city planning (eg., see Ma 2002); and eventually widening the range in the definition of an unstable, multi-functional spatial balance for the periurban landscapes worldwide. Nonetheless, it will be in Asia —particularly in China — where ongoing experiments on sustainable urbanization may reshape the future patterns for the whole planet. This was in fact a concomitant interest for the study.

4. Results and discussion

4.1. Results

From the application of the mensurative experiment, one of the main empirical results was identifying similar size typologies and gaps for all landscapes:

1. It was evidenced the existence of a single, main characteristic space of the landscape (the "Matrix"): Typically the largest unfragmented, still-remaining space of agricultural use, except where advanced urbanization processes had already taken hold.

2. A common -yet dynamic- size threshold between large patches ("Aggregates") versus the smaller patches ("Outliers"): Approx. at 100 - 200 ha.

   This threshold-range seemed related to overall landscape dimension: Correlation became 0,72 (significant at 0,05 level; two-tailed) once Lancaster County was excluded. On the interpretation, this is the largest landscape, greatly affecting the result of correlation indexes; we had to consider it as a highly-remarkable exception to the general rule, therefore.

3. As another unexpected outcome, it was detected a size-threshold inside the "Outliers" class (the small patches), allegedly between medium-sized and the smallest-size typologies: Approx. at 15 - 30 ha.; yet this threshold was seemingly independent of landscape dimension.

For the discussion, those empirical results seemed quite coincident with AWO functional interpretation on patch typologies: Similarly to AWO criteria, we were at ease defining experimentally the matrix and the large patches, versus the smaller ones. Nevertheless the analysis evidenced a new threshold, defining the typologies of the medium vs. small patches.

As an example of the functional -as well technical- relevance of the classification, in almost all mosaics the analysis on size variance evidenced the most relevant threshold was one defined by the largest patch of the landscape (the matrix), against the rest. This typology accounted for over 90% of the total agricultural land in one case (P.Vic, BCN), almost conflating the total agricultural land-use with the matrix functional typology (figure 4).

Results seemed to corroborate the existence of domains of scale, against the scale-invariance hypothesis. This is, the patch-typologies effectively appeared defined by common variance thresholds or size clusters. Even if formulated as dynamic ones (relative to landscape overall extension eg.), the definition of different typologies of spaces as functional aggregations may have more relevance, at the landscape level, than the measure of the components' internal variability (eg. inside each size-class typology).

Table 3. Total area of landscapes and obtained thresholds: Aggregates or large patches vs. Outlayers; Medium Outlayers vs Small Outlayers (small patches).

LANDSCAPES / AREA THRESHOLDS	N.Pioneer	Connestoga	Bages	Conca	Penedes	*Valles*	Vic	Huairou-Miyun	Hefei-Chaohu
Total Area (Km^2)	399.5	1190.3	157.5	205.1	328.2	662	257.9	275.5	202
Threshold (ha): Aggregates/ Outlayers.	130	112	119	109	181	209	102	181	70
Threshold (ha): Medium/Small Outlayers.	30	30	27.5	17.6	30.2	14	12.2	15.2	20.8

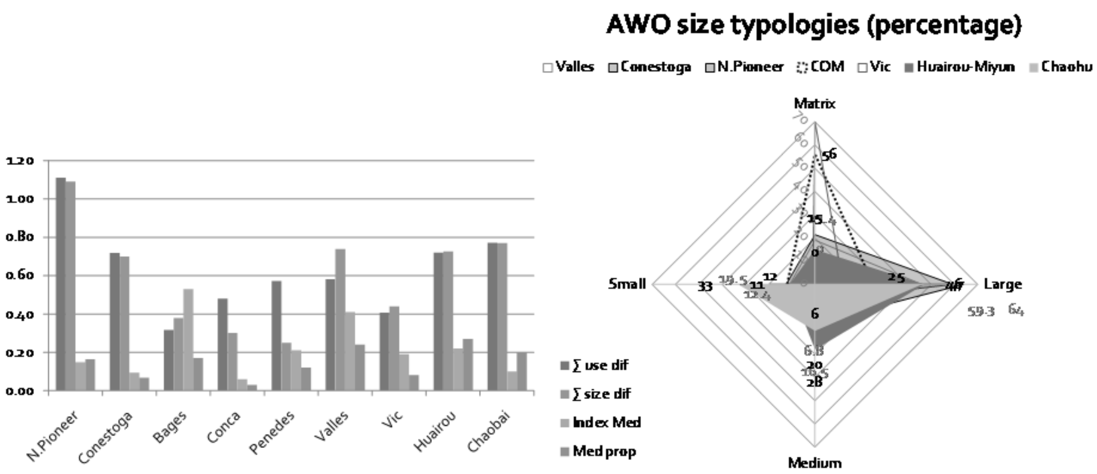


Figure 4. Comparative on AWO typologies for the nine periurban landscapes.

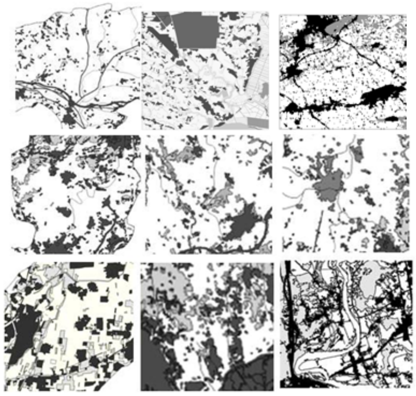


Figure 5. Visual samples of the research mosaics (10x10km aprox.).
Black: built-up; white: agriculture; grey: woodlands.
Left to right and top-bottom: 1 C. de Barbera BCN; 2 Hefei Chaohu 安徽; 3 Lancaster County PA; 4 P.de Bages BCN; 5 P. Penedes BCN; 6 P. Vic BCN; 7 Huairou-Miyun 北京; 8 P. Valles BCN; 9 N. Pioneer Valley MA.

Summarizing the results for the different regions, some of the best compositional situations were identified in Barcelona region. These are presented in the distribution comparison of table 3 and figures 4-5.

Results in the Conestoga landscape pointed as well to the existence of a highly desirable situation, with an agricultural matrix as the most important single space, while having a low index of medium patches -both indications of a lower rate of suburban sprawl. On the contrary, for the North Pioneer Valley even the definition of the matrix typology had to be discussed, as 14 patches were in this category instead of the usual one or two.

With regard to the results of the two Chinese landscapes, the agricultural matrix was clearly present, yet not in the range of desirable values anymore. In addition, there was a relatively high density (and mean area) of both medium and small patches. Results pointed to a specific situation in which a mix of intensive land uses coexist in quite a tight pattern. This was particularly the case of the Hefei-Chaohu urban fringe, where agriculture and dense built-up areas appeared to mingle with very few natural, temporary or unproductive (marginal) land uses.

4.2. Discussion

In general, results from our analysis on typologies of patches and thresholds were easy to relate both to existing literature on the ecological processes necessary to maintain or increase systems' global diversity and resilience; as well to the universal AWO requirements on functional structure and landscape pattern. This broad coincidence with empirical observations and observed thresholds (from ecological management studies, or from Panarchy theory eg.) equally seemed to confirm the functional meaning attached to the spatial typologies defined by the AWO conceptual formulation.

This was not deemed to be a chance occurrence anyway; but rather a fact deriving, mainly, from the compositional requirements for the matrix and large-patch typologies, on which most of potential ecological functions and services depend (with area-thresholds implied): For example, the fulfillment of the specific requirements on composition and configuration for natural habitats mostly depend on the existence of large patches (usually over 100ha –table 2), which foster overall connectivity potential, internal diversity and spatial resilience to the whole landscape.

Just by stressing the need to aggregate as much as possible existing land uses, we may effectively avoid degradation and fragmentation of natural land. Besides, the AWO spatial concept remarks the need to have a diversity of open or marginal space (mainly outliers or small-size patches) fostering variability, ecological resilience, and enhancing the system's long-term survival to alterations. Adding to this, and although formulated as a multi-layered, multi-functional planning tool, from the start the AWO conceptually gives preeminence to natural processes over human ones.

This synthetic view on compositional optimization may be considered, in fact, as a pre-condition for configuration designs, as the very existence of those key spatial typologies (and respective area) will be a strong determinant for design solutions. To place this in context: A situation in which the matrix and large spaces are compositionally weak inevitably leads to an increase in entropy (decreasing variance in size typologies, and increasing internal land-use diversity). Therefore, to the need to prescribe "offensive" scenarios –with intensive, high-cost solutions- to counter this trend accelerating natural and human system's disruption.

Another evidence of the same process of degradation, the amount of medium-size patches is considered by the study as an early-warning signal, probably reflecting a critical transition in landscape properties: Similar to thresholds defined for functional processes, they are an indication of a shift in the system's scale-properties and functionality –allegedly, to the "complex nature of the global systems" (*sensu* O'Sullivan et al. 2006: 614); breaking away with the coevolutive, self-organized processes of vernacular landscapes.

In practice, both the dysfunctional land-use patterns and the potentialities observed would not have been detected in any individual recount of variables, or a battery of them. An integrated approach is required in which we consider key compositional factors altogether (variance on size and land-use diversity), at a given time and place; identifying from the beginning the main characteristics which foster territorial systems' integration and sustainability. As corroborated by our findings too, these issues are incorporated into the spatial concept's guidelines in effect -if only qualitatively and fragmented.

In the study then, by applying an original contextualization and de-contextualization sequence was made explicit a quantitative procedure for a guided spatial analysis (figure 2). At the end, the method and its deployment effectively allowed for a comparative analysis on different study cases, from a universal base.

The JMV+D mensurative experiment emerged in fact from a hypothetical-exploratory approach, or the test on the properties of the AWO concept as a theoretical artifact (*sensu* Rhoads 1999). As such, it was an initially unexpected result arising from testing the technical and functional capacities of the concept; which started, nonetheless, by considering the conceptual framework on which the normative formulation is based, and the possible interrelations with the paradigm of living systems' theory. This approach was instrumental in synthesizing the basic requirements of the concept, always spiraling around the key spatial-heterogeneity (entropy) variables.

Nevertheless, to have into account the inherent multiplicity of dimensions involved in a holistic research (and the necessary epistemological dialog inside holistic approaches), we should remark probably the fact the present study spans a diversity of scientific reasoning methods: From the analysis of a compilation of basic postulates on the desirable distribution of periurban mosaics (which include human intention and agency), to the definition of an experimental method to test and apply in practice a theoretical concept; or from the descriptive study of study cases, to the statistic or probabilistic approach required for comparative analysis. For instance, statistical comparison among cases (and the optimal) was an intrinsic procedure of analysis, making evident the relational aspects implicit in the measure of internal diversity.

The array of methodological and scientific approaches involved should not overshadow, anyway, the fact that besides its central hypothetic approach, the present study can equally be considered, at the end, a synthetic development on the spatial-concept's criteria: A development mostly coincident with its normative, problem-solving nature, and applied goals (Forman, R.T.T. 2007, pers. comm., 24 Sept.).

This multiplicity nonetheless seems to fit well into the diversity of comparative methods required for the holistic, integrated analysis of territorial systems. This kind of synthetic approach may help, in fact, in testing the general case or validity of the conceptual frame when developing applications from a normative perspective, inside holistic conceptual frameworks: Eventually, opening new avenues for the analysis of territorial systems from analogy to basic postulates of non-linear dynamics, and living systems' theory.

As a summary, in the research we hypothesized the AWO spatial concept allows for (and promotes indeed) a methodological path satisfying the precepts for integrated analysis, and functional optimization of coupled natural and human subsystems –the Compositional Optimization Method (COM); a path that finally leaded us to the formulation of an applied, original solution for the strategic planning of the heterogeneous landscape mosaic (the JMD+V model). Or put in another way: Following from the AWO concept's stated goals for planning, we provided a genuine development proposal, based on the joint optimization of two-key compositional variables of spatial (functional) heterogeneity: Diversity of land uses, and variance on size of patches; one which can measure deficits and potentials, through the mensurative experiment defined.

As a territorial macro-diagnostic, this synthetic method effectively allowed for analysis and characterization of periurban sprawl. Arising from the interpretation of empirical evidence on functional land-use and size typologies of the landscape mosaic, it equally provided hints on ongoing development characteristics, as well possible territorial self-organization processes.

For example, from the study it was made evident the critical importance of maintaining the still-remaining agricultural matrix inside periurban landscapes, and its balanced relation with certain typologies of spaces (especially when decreasing). As a generic issue for territorial planning then, when there is a sharp decrease of the matrix-typology below desirable levels (aprox. 50% of total area; figure 3), and a relative increase of medium patches (from aprox. 30ha to 100/200ha; table 3), configuration designs will be crucial to reconnect the landscape mosaic.

Along with diagnostic results then, with our approach it seems equally possible to define alternative scenarios, following goals, targets, and drivers inside a specific planning context. This just by keeping track of the two main factors fostering territorial resilience, in a joint optimization approach: Heterogeneity of land-uses, and size-variance of patches (figure 2, steps 5-6). In this regard, the periurban landscapes presenting over 50% compositional differentials against the desirable range, may call for a scenario of positive intervention (figure 4); one which should be proactively planned, as in the case of Pioneer Valley (MA) for instance.

The differentiation of such "offensive" scenarios (figure 2) is considered in fact a helpful tool when designing planning strategies, and for the definition urban-growth equilibrium equations (*sensu* Berling-Wolff and Wu 2004). Adding to this, such spatial-integration methods may require little effort to be implemented as guidelines for further modeling -in Agent Based Models, for example.

Needless to say, results from application of this mensurative experiment are to be questioned and contrasted by new studies. Nevertheless, it will be so from a universal referent. We have to remark, this way, the potential value of comparative approaches arising from normative frameworks, once they are conceptually and empirically validated: Especially when derived from widely-acknowledged literature, and contrasted applications.

4.3. Study cases

Operatively, we need to remark the relative sub-optimal situation of most of Barcelona landscapes (and the urban region as a whole) in AWO terms -a valuable asset for the development of our approach. In this regard, the concentrated settlement pattern in Mediterranean-dry regions has probably a good part to do in the explanation: Presenting a characteristic lower land-consumption, maintained by regulations and usual practices -even if unconsciously. This close-to-desirable output may have arisen, in fact, from unwritten cultural values and the willingness to avoid (just for survival needs) land-waste and resources depletion (eg. scarce water, fertile soil or firewood).

These were stringent requirements that shaped, in the first place, the ecology of the highly-humanized Mediterranean landscape since millennia: Agriculturally dependent, while in a fragile equilibrium with the surrounding ecosystems; a slow, subtle outcome providing increased diversity, which emerged from agricultural practices almost lost. Another example yet on how human action can be a positive agent inside ecosystems. This highly-desirable, close to conceptual results for the periurban Barcelona landscapes is in fact coincident with world-scope comparative studies, at regional scale (see Forman 2008).

As in many vernacular landscapes, the old daily-markets' area of influence (defined by one-day trips inside a watershed) was both a physical and administrative unit, fostering local identity. Yet nowadays, the traditional socio-environmental containment seems to be disappearing in favor of the current driver of suburbanization, based on cheap-energy access; one which is locally unsustainable, and increases the regional ecological footprint. This outcome was easily noticeable in the study by the distribution of land uses; between the more and the less-urbanized landscapes of the region, for example (Valles and Penedes against Vic or Bages; figure 4).

In quite a different and advanced stage of suburbanization, Pioneer Valley MA hinted to a rampant low-density urbanization and the return of forests, probably from abandonment of former agricultural land (now almost residual). This is a landscape where a convoluted mix of the three uses has almost become the predominant cover. Even so, according to results it is still possible to plan for a different future, as it retains some prime agricultural land -thanks to property-easement policies, mainly. The discussion whether the community-feeling linked to the place is already fading, or if a 'small-town spirit' is to remain can be related through compositional evidence, in this way, to the suburbanization processes taking hold.

In summary, although not having a clear foreseeable outcome, our results challenge possible consideration of this landscape as one with a 'right balance' between human and natural systems anymore. Without a proactive and comprehensive planning strategy (offensive scenario), the highly-fragmented configuration may likely follow the same fate than nearby Boston urban region, with receding and disappearing agricultural land.

In contrast, the macro-diagnostic of the Conestoga landscape pointed to a close-to-optimal situation for its main agricultural patch (the matrix), and a lower index of medium-size patches. Adding to the exceptional attachment to the 100ha (approx.) threshold for the "large-spaces" typology (which is not altering the relative weight of typologies in practice –table 3; figure 4), this is a situation which still allows to focus on the maximization of diversity and variance for the rest of patch typologies; eventually resulting in a more protective scenario-proposal.

As hypothesis, thresholds and desirable percentages of patch-typologies here might indicate the persistence of certain self-organizing, coevolutive processes on the vernacular landscape. Even so, we found a lot more large urbanized patches than desirable: Caution should be taken to avoid the confluence of additional linear infrastructures on the remaining agricultural land (which eventually may conflate in a very large urban space, the new matrix).

Although certainly far from the traditional model of Feng-Shui, according to results the situation in both Chinese landscapes was considered still in a desirable condition, arising from its high-density settlement patterns and multifunctionality; away in this respect from the horizontal, low-density sprawl of Western countries. However, if not regulated to avoid further densification and spillage, it will probably recreate the characteristic scrambled-city pattern of Beijing, and other large conurbations (Yu et al. 2011).

In order to avoid total loss of natural functionality in the remaining (non-built) land, the strategy to "sponge" (or clean-up) the intensive land-use patterns should be stressed. This strategy should put into practice, for example, a combination of a) increased protection of the few remaining marginal spaces, b) the definition and regulation of large forest patches, c) design of green-heritage networks and recreation corridors, and d) avoiding land fragmentation and the "call effect" on local developments, coming from construction of linear infrastructure.

As a shared outcome then, it was detected a close-fit between the more-desirable natural values on landscape distribution (as stated by the AWO concept and ecological studies -table 2), and the actual land-use distributions of existing traditional landscapes and communities (eg. Plana de Vic, Bages, Conestoga).

Arguably, the evidence obtained from our method came from the fact that we were walking 'in the same shoes' (with the same synthetic goal) as the AWO normative concept: Looking to spatially-define territorial sustainability within a dynamic, flexible balance comprising human and natural subsystems. Closing the loop, the reference to human intentionality and perception comes back for reappraisal: Because human actions dominate, the adaptability of the system is mainly a function of the social component (Walker 2005: 84). Community living-standards could be, conceptually, the key to define the dynamic, unstable territorial balance required for periurban landscapes.

At the end, compositional evidence results mainly from ongoing human activities, and it is not difficult to anticipate the spatial outcome (eg. for habitats, connectivity thresholds) of a given land-use policy or decision. We have indeed a responsibility for the 'spatialities' (spatial qualities) in which we live and construct our lives (Massey 1999: 275).

Which urbanization model may be the most desirable in a near future then? Is it the apparently haphazard, dense Chinese mix which, eventually regulated, shows promise of a much lower rate of land consumption than most Western low-density developments, at the same time than maintaining higher productivity? Or is the Conestoga case which, in the Western context, explicitly points to the social values of stewardship of the land? Or is it simply the opposition to land-waste, that has shaped (since long ago) a close-to-optimum, balanced situation of vernacular landscapes -even if unconsciously; a situation maybe still reflected in the periurban areas of Barcelona region nowadays?

The implementation of this original method as a planning tool may increase, in any case, the effective chances for implementation of ecological resilience and spatial sustainability inside actual mosaic distributions; equally providing a reliable interpretation on the actual diversity of highly-humanized landscapes. Although arising from a normative formulation, developing this compositionally-guided approach allows for a dynamic definition and comparison of study cases (landscapes), which characteristically fits into acknowledged thresholds of ecosystem service provision; equally coincident with the enhancement of territorial sustainability premises, and entropy minimization goals.

5. Conclusion: Guidelines for periurban landscapes

From the test of a normative spatial concept (Aggregates with Outliers –AWO; Forman 1995), a comparative study on worldwide landscape's functional patch-typologies was deployed. Following an original method, we developed a compositional macro-diagnostic tool which stated spatial deficits and potentials of the landscapes. The joint maximization on key compositional variables (diversity of land-use and variance on size, or JMD+V model) fostered a synthetic approach considered as a technically as well functionally-relevant tool for strategic planning.

In this respect, the method allowed quantification on the main landscape's distribution features inside existing, desirable or expected mosaic configurations; helping to build a narrative or plot regarding the actual situation of different cultural landscapes worldwide. From the application done, it is equally feasible to define an unstable or dynamic equilibrium, for the urban-natural dichotomy inside periurban landscapes. As a "thought experiment", it becomes a metaphor for territorial sustainability. At the end, the implementation provided a coherent narrative, considered useful when defining and applying the required frameworks of territorial sustainability, as for contrasting different cases and scenarios.

This original method and implementation can be equally considered one of the many experiments implemented in the search of integrative methods, inside holistic approaches. At the end, we will give direction and guidance to planning and management proposals in strategic issues -for example, the desirable levels of spatial heterogeneity, within existing or given constraints.

The implementation and comparative analysis among diverse locales, times and scales was based at the end on the conceptual relevance of the spatial concept. Despite the limitations of normative approaches, what is urgently required is the functional explanation of integrated socio-environmental processes at the landscape and region levels: One that can be applied to the task with the goal to increase adaptability of the remaining cultural landscapes, inside growing mega-regions.

Human action and intention are the main determinant in this process; so the need of proactive, regulatory approaches designed with the goal to foster the desirable outcomes or trajectories is a must for integrated-planning approaches: Countering the "business as usual" (limited) strategies still enduring today, by widening the prospective range and the actual possibilities; accepting our responsibility on the spatial qualities of the territory we create, this way.

As future prospects, our preliminary empirical findings need to be contrasted with new study-cases. The fact this methodology is easy to use also suggests it should be further developed and tested without much difficulty. Integration with existing methods and applications allowing for the diagnostic of periurban landscapes (based on compositional thresholds), is equally considered one of the main interests: Ultimately, with the shared goal of developing a compilation (or atlas) on the actual situation of the world landscapes from a coherent, functionally-integrated perspective.

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Sense Shaping Place: Repositioning the Role of Sense of Place in Social-Ecological Systems from a Bioregional Planning Viewpoint

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Abstract. Dynamic landscape change affects and is affected by human attitudes. The effect of pattern on process has been investigated mainly in landscape ecological sciences, focusing on whether and how the human influence on spatial organization of landscape creates stable, functioning ecosystems. In earlier ecological studies, despite embedding their values, perception and attitudes when delineating a place, humans have been treated as an independent, separate entity. Equally, the ecological imperative expressed through operational models of conservation planning changes the physical organization of landscape in such a way that it affects public connection to landscape and influences views and attitudes towards ecosystem governance. A more comprehensive understanding is needed of these two phenomena, addressing the linkages between ecosystem conservation and how people respond to dynamic change. Therefore we employ 'sense of place' as a broad concept to assess and evaluate the way in which people shape their responsiveness to place through a bio-regional planning approach. . This paper focuses on the attitudinal dimension of sense of place in planning-based activities. The results suggest that although place connection strongly empowers protective and ethical-based actions, it remains unclear how planning renders the negotiation of the different actors' values with respect to the concept of place. A conceptual framework is proposed, to assess the role of sense of place as an integrative concept in understanding the linkages of social-ecological systems and the need for future research to investigate how planning is receptive to the multitude of actor's values and attitudes that shape social-ecological changes across the landscape.

Keywords: sense of place, bioregional planning, environmental ethic, social-ecological systems, landscape planning

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1. Introduction

Landscape change has increasingly been recognized within interdisciplinary perspectives to be a process that is inherently influenced by an interacting social-ecological system (SES). This process is not deemed to be static, but rather it is a dynamic process of transaction between human values and functions that have evolved as a consequence of past resource use, policy and social response. The process of landscape creation as a human territorial region is described by Mumford (1938:367) as "a complex of geographic, economic and cultural elements. Not found as a finished product in nature, not solely the creations of human will… the region… is a collective work of art". A human territorial region or a "place" is the sum of all interactions between human activity and preference and biophysical resources, whereby a bioregion indicates a similar pattern of land use and ecosystems (Brunckhorst 2001; Slocombe 1993). Place therefore is a geographical setting that is imbued with meanings (Altman and Low 1992; Tuan 1977). The meanings encompass the interaction between the components of utilitarian or intangible value of the natural resources within the physical setting. The conceptualization of meanings for that physical setting to be turned into "place" is unique, which correspond to how individuals develop their interaction with the components. This relationship is not easily categorized as Cheng et al (2003) suggest as they attempt in a body of literature to dissemble place creation into distinct constructs and dimensions based on each disciplinary epistemological and ontological perspective (for example, refer to Trentelmen 2009). The cognitive, affective and conative perspective of place rooted in human geography (Relph 1976; Tuan 1977) and environmental psychology (Canter 1977) seems to fit and be in tandem with bioregional thinking that emphasizes the "terrain of consciousness" (Thayer 2003), which also connects or associates with the development of one's awareness of the natural world which is important in maintaining the ecology of the place.

The emergence of bioregional planning has reinvigorated the idea of "place" in land use planning and conservation. Hence a paradigm shift from the previous commodity-centric thinking and top-to bottom approach, to a more flexible-collaborative and integrative approach of human and ecological needs has occurred (McHarg, 1969). Recent research suggests that place-based values and meanings have been increasingly recognized in the field of landscape and urban planning (e.g., Smith et al 2011; Stewart et al 2004), natural resource management (e.g., Windsong 2013; Brehm et al 2012;), geography (such as, Brown and Raymond 2007; Tonge et al 2013;) and sociology (e.g., Ulrich-Schad et al 2013;). While the concept of "place" varies among these studies, they have used place-based meanings and values as a broad concept to characterize the behavioral perspective of the way in which individuals respond to and shape management outcomes. For example, the idea that through their understanding individuals ascribe meanings and values to their place, has been found to strongly influence support for resource consumption fee (Kyle et al 2003) and individual's awareness towards local issues and environmental impacts (White et al 2008). The current processes of devolution and globalization makes the need to understand "place" is important, due to these processes knowledge is gained and actions are taken locally. This substantially depends on the process of humans becoming native to the place in which they are living within the natural parameters in a way that the local ecology is restored (Dodge 1981).

Navigating the range of literature along these threads, however, a deeper understanding is required to further expand upon the way in which the behavioral aspects of sense of place feed back into the ecological system. Recent studies on how humans conceive their place values and subsequently actions that shape their ideas regarding the use of future resources have gained momentum. Studies in, for example Brown et al (2004); Alessa et al (2008) and Donovan et al

(2009) have explored the convergence between social and ecological system and how this implicates planning and conservation which considers the community's values in relation to the place. These findings suggest that social and ecological assigned values may overlap which can assist planning processes in regard to ensuring sufficient support from the communities with respect to meeting their socio-economic goals. Even so, in terms of the reality of the realm of planning and conservation, the inclusion of values or sense of place per se has been sporadically considered, due to the ambiguity of multiple perspectives (Kalterborn, 1998) and the complexity of inherent values or sense of place that is not necessarily spatially explicit (Bott et al., 2003). Consequently, while specific place values for specific stakeholder group are accounted for in planning processes, it disrupts other group's values. Research has shown that the disruption and erosion of place's values and meanings represents a significant threat to one's associated socio-psychological functions (Brown and Perkins, 1992; Burke, 1991; Erikson, 1994) including social displacement or forced migration (Fried, 2000; Milligan, 2003). In terms of the result of place values disruptions, the attitudes process presents a contradictory view in relation to supposed place-protective action. Brown and Perkins (1992) and Inhalan and Finch (2004) characterized this attitudes process as including an initial shock and denial, followed by psychological stress and other mental issues, and finally by acceptance. This directly affects the resilience of the so-called social-ecological system, as the important motivator for place-protective behavior which stems from people attempting to prevent the loss of assigned place meanings (Twigger-Ross and Uzzell, 1996). Hence, from both a theoretical and practical perspective, the sense of place concept presents common ground for examination in planning and conservation efforts that influence the resilience of social-ecological systems.

In this paper, we focus firstly on bioregional planning as an umbrella concept of the planning paradigm which is recognized as interlinked with social-ecological systems. Second, we conduct a comprehensive review of the literature related to sense of place and its behavioral perspective, with a focus on the link between place connection and stewardship characteristics towards planning and conservation initiatives. Subsequently, we propose a theoretical framework that underlines sense of place as an integrative concept and identify the requirement to understand the multitude of place values among social actors that shape social-ecological system in the context of bioregional planning.

2. Materials and methods

The review is based on primary and secondary literature sources reported in the root disciplines of cultural and humanistic geography, sociology, environmental psychology and applied disciplines, in landscape and regional planning, ecosystem management and resilience. The set of keyword combinations used to direct the literature search were sense of place, place attachment, bioregional planning, social-ecological systems, place-based governance and environmental ethic. A computerized searching technique was applied to online database navigation from Science Direct, Springer, Taylor and Francis and Scopus. Papers were extracted comprised of articles related to the theoretical aspect and empirical studies, which included the quantitative and the qualitative approach. Literature was chosen to illustrate an in-depth understanding of the theoretical side of people-place concept and its role in enhancing both ecological functioning and the social system. A greater emphasis was placed on literature that addresses the characterization of environmental stewardship in the form of attitudinal responses towards development and conservation strategies. While the use of secondary sources offers a broad overview and immersion into the body of literature, the primary sources were located and synthesized accordingly. This two-step review process was conducted, thus avoiding the probability of erroneous interpretations of the results (Bui 2009).

3. Literature Review

3.1. Background: Bioregional Planning – Re-envisioning Humanity's Role in Social-Ecological Systems

The fundamental rethinking of natural resource management, conservation and reconciling human needs in land use planning has led to a paradigm shift from a rational planning approach towards alternative integrated planning approaches (Scrase and Sheate 2002). In this age of complexity where the patterns of nature and society are interwoven into an interconnected web of domains and processes, many planning approaches struggle to frame the uncertainties of the future as a result of our actions today. Current advances in ecosystem sciences, sustainability sciences and other related disciplines acknowledge that socio-ecological systems are interlinked, creating an intertwined linkage of systems that are influenced by each other (e.g., Berkes 2004; Crane 2010; Miller et al 2010) . Different approaches have been debated on how best to protect public interests. The failure of a traditional top-down planning approach has been noted by advocates in planning and environmental management fields (see for example; Blair 1996; Oddie 2004; Scott 1998). In particular, it has been critiqued as being overly relied on in regards to the aspect of growth projection (Halstead 2013; Loveridge 1972), the inability of local government to solve trans-boundary environmental problems associated with urban sprawl (Bruyneel 2009; Godschalk et al 1977) and disempowerment of local communities in decision-making (Harris 1994).

More importantly, Diffendefer and Birch (1997) claimed that these responses are rather symptomatic of the core issue of a centralized command and control approach, highlighting an inability to counteract against a utilitarian view of specific actors in satisfying their needs. Furthermore, public dissatisfaction with government, has led to mistrust in science as a base for political decision-making (see for example; Gauchat 2012; Reynolds 1969) which often does not reflect the concerns, values and needs of the communities (Moote and McClaran 1997). Consequently this has necessitated a social restructuring of planning in order to manage effectively competing land use interests between various social actors (Frame et al 2004). In the context of regional planning and conservation, bioregionalism offers an alternative approach for governance that involves both social and political restructuring. Birkeland (2008) and Diffendefer and Birch (1997) assert that the subsequent transformation of governance implies the need for a multi-faceted platform designed to achieve ecological conservation, which in turn facilitates social, ecological and economic sustainability.

A more overt approach for the inclusion of sense of place in planning and conservation through bioregional planning is needed as a means of addressing these concerns. While bioregions, as defined earlier, are patterns of land use and biophysical similarities, they also emphasize the "terrain of consciousness" – a place where the inhabitants are aware and have their own ideas regarding their existence or thoughts concerning how to live in that place (Relph 1976; Strobet 2003; Tuan 1977).

Relevantly, while earlier fragmented research and planning fields isolated society from resource use, bioregionalism under these conditions expresses the self-reliant characteristics of several multi-faceted components in the planning system. Sale (1993) noted that the core foundation of bioregionalism is the in-depth understanding of a region's resources and geography, in which dynamic social and economic development operates within the ecological carrying capacity. This philosophy underlines the importance of an ecological-planning approach so as to be responsive to people who inhabit the place (Thayer 2003) and to enable community empowerment in decision making (Harris 1994) in order to facilitate and achieve long-term ecosystem conservation.

3.2. Sense of Place

The subject of place as an experiential place or "sense of place" has been explored from various disciplinary perspectives bounded by their own epistemological foundation in conceptual understanding. Early development in geography indicated *place* as a *locale* of physical properties in a geographical context (Lew 2008). Since then, humanistic geography studies have enriched the concept by suggesting that place is not merely a physical entity but it is composed of complex experiential and psychological dimensions attached to a particular physical continuum. This particular discourse is endowed by humanistic geographers such as Relph (1996:907-908) asserting that place is not just a mere connection to physical properties of the natural environment but rather "tightly interconnected assemblages of buildings, landscapes, communities, activities, and meanings which are constituted in diverse experiences of their inhabitants and visitors". Drawing upon this phenomenological experience, he further suggests that development of place not only evolves from individual-meaning, but is presented as a collective form of inter-subjective, shared values communicated between inhabitants (Relph 1996). Such complexity in conceiving and establishing clear development of place has been highlighted by Butz and Eyles (1997:1) as "rooted in theories of social organization and society, and as being variably and contingently ecologically emplaced".

Considering these circumstances, "a sense of place" is therefore associated with the idea of experience that turns the ecosystem space into a place. Tuan (1977:6) in his seminal work pointed out that space turns into place "as we get to know it better and endow it with value". In a similar manner, Relph (1996:909) suggests 'a sense of place' is an awareness of the "inherent and unique qualities of somewhere". Implicitly, this understanding imposes a dimension of awareness or sense that qualities (environmental or social) can be achieved and maintained (Tuan 1980). In other words, "sense of place" is composed of "personal memory, community history, physical landscape appearance, and emotional attachment" (Galliano and Loeffler 1999:2); places therefore, in addition to a physical setting, are an amalgamation of meanings and values, (Sampson and Goodrich 2009) and socio-psychological processes (Gieryn 2000; Stedman 2002). Consequently, qualities that can be classified as subjective to the meaning of anything – culture, own identity, imagination or memory – influence the identification of physical or social properties when describing one's "sense of place" and therefore presents certain challenges.

Despite the complexity of theory and practice in place-related research, the theoretical construct of "sense of place" has been divided into two main lines of inquiry. The first approach conceptualizes three components of "sense of place", constructed as place dependence, place identity and place attachment that overlap each other in one instance and subsequently override each other in another (Proshansky et al 1983; Vaske and Kobrin 2001; Williams and Roggenbuck 1989). Alternatively, others have viewed "sense of place" as a tripartite of three multidimensional constructs, with each construct representing the component of cognitive, emotive and conative of human consciousness (Steadman 2002; Jorgensen and Stedman 2006). Organizing these constructs in alignment with human consciousness, place identity can be conceptualized as the cognitive component while place dependence is associated with the conative_component and place attachment as the emotive component of sense of place. Place identity according to Proshanky (1978) refers to an intersection of personal values, beliefs and goals within the physical setting, and hence an idea of how a physical setting becomes purposeful and meaningful to life. Place dependence is a functional relationship illustrated when a place is instrumental in fulfilling certain needs of the individual (Stedman 2002). Place attachment on the other hand reflects the emotive part of awareness, thus positive bonding develops between the individual and their natural world (Altman and Low 1992). Other studies, for example by Rollero and De Piccoli (2010), articulate constructs into distinct elements but also found that the constructs are correlated, comprising cognitive, affective and conative aspect of place.

Environmental psychologists have used place attachment as the denominator for a sense of place in their theory development and practice and their approach presents a stark contrast to epistemological and research approaches (Graham et al 2009:15). Their primary focus has been on investigating the psychological process of mental cognition/development of an individual's connection within the physical context. This range of researchers has emerged concurrently with the objective to inform the behavioural process in planning. Altman and Low (1992:165) define place attachment as "the symbolic relationship formed by people giving culturally shared emotional/affective meanings to a particular space or piece of land that provides the basis for the individual's and group's understanding of and relation to the environment". A symbolic relationship is experienced at the scale of individual, group or culture inculcation, through the "interplay of affect and emotions, knowledge and beliefs, and behaviours and actions in reference to a place" (Altman and Low 1992:4). However, the study of place attachment in environmental psychology has been criticized for its sole emphasis on the psychological process of development of place (Sime 1995). In contrast, humanistic geography emphasizes the phenomenological experiences of how people understand places and shape the role places play in their life, while research into environmental psychology has tended to separate the composite experiential of place into discrete elements that are measured in a positivist approach.

Nonetheless, the contribution of place attachment and identity in environmental psychology has been widely accepted in planning practice due to its ability to conceptualize the emotive bonds between people and place- a subject that many planning realms strive hard to manage. Regardless of various disciplinary orientations in understanding place, they are underpinned by the core principle of human beings embedded in a particular environmental context that involves interaction of experience and physical components. Therefore we employ "sense of place" as a broad concept (Figure 1) to capture the tripartite construct of place attachment, place identity and place dependence rather than articulating the constructs into distinct individual elements. The geographical space turns into a place when individuals assign a value corresponding to the geographical characteristics and their interaction. The human conception of space involves a process of categorization and discrimination of geographical discrete elements (Burnett 1976) and this subsequently influences attitudes towards how it should be managed (Cheng et al 2003; Kruger 2001). This suggests that the combination of psychological domains as illustrated in Figure 1 can better understand how humans ascribe values to the natural world including the processes taking place and predicting the attitudinal responses that can influence the future landscape. Our study revisited the concepts and ideas as outlined by the previous works and places them in a new light by framing the context from a social-ecological perspective.

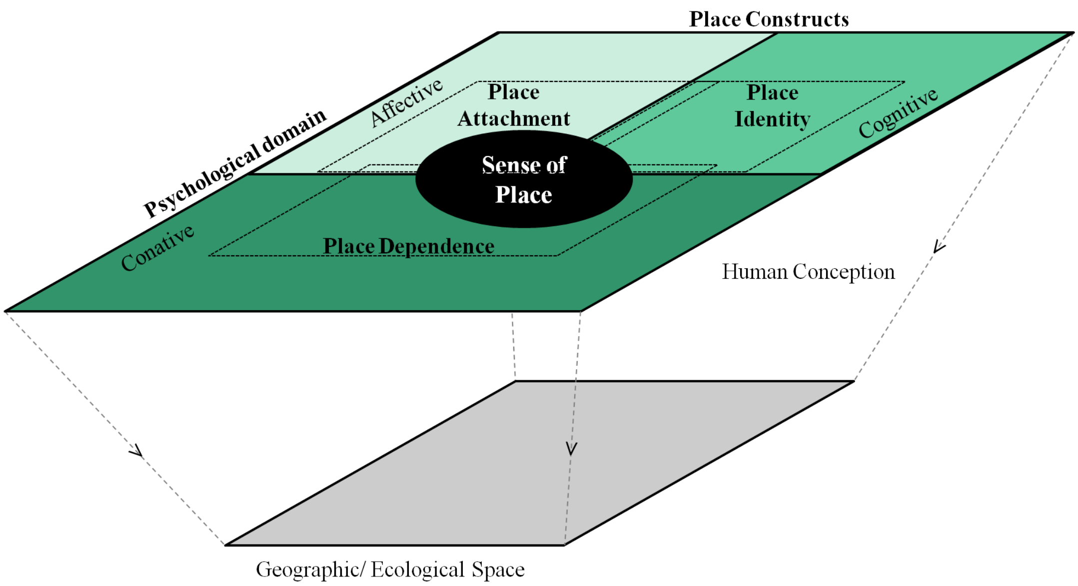

Figure 1. Sense of place as a broad concept that combined multiple constructs and psychological domains emplaced in geographic and ecological space.

3.3. Grounding a Sense of Place in Bioregional Planning

A bioregional planning approach explicitly addresses the need for conservation planning in maintaining ecological processes and functions. Scientific knowledge of landscape ecology underlines the set of principles used in modifying the spatial organization of the landscape when achieving balanced performance-based ecosystem outcomes. This may differ from the socio-cultural context, within which opinions, perceptions and values that are attached to particular landscapes are contingent on changes of the biophysical components. This dual perspective of conceptualizing the environment is crucial, as the scientific view of organizing the landscape is coupled with real community involvement in the planning process. In reality social opinion is not always aligned with the intended outcomes of conservation planning. Therefore, this poses a challenge for planners when considering the dualistic realm of an environmental model such as that described by Rappaport (1968) cited in Ndubisi (2002:111-112):

> *"Two models of the environment are significant in ecological studies; the operational and cognitive. The operational model is that which the anthropologist (scientist, planner, designer) constructs through observation and measurement of ecological entities, events and material relationship. He takes this model to present analytical purposes, the physical world of the group he is studying…. The cognized model is the model of environment conceived by people who act in it…The important question concerning the cognized model, since it serves as guide to action, is not the extent to which it conforms to reality (is identical to operational model) but the extent to which it elicits behaviour that is appropriate to the material situation of the actors, and it is against this function and adaptive criterion that we may assess it"*

Humans enter into the ecological system by being incorporated as another set of values or determinants (Cosens 2013; Uy and Shaw 2013). The cognitive model reflects on how people conceptualize and participate in the landscape by creating a specific meaning or value associated with the idea of 'ecosystem'. Within the context of this study, this phenomenon is underpinned by the "transactional concept" (Zube 1987) and the "interactionism perspective" (Greider and Garkovich 1994). Zube (1987:38) coined the idea "transactional concept" in order to explain human-landscape relationships by suggesting the notion that "both the human and the landscape change as a function of the transactions". He suggested that active social participation and exploration in nature, creates an experience that contributes to the attribution of value towards nature. From the discipline of sociology, Greider and Garkovich (1994:1) argue that landscape is the process of social construction in nature and:

> *"[landscapes are] the symbolic environments created by human acts of conferring meaning to nature and the environment, of giving the environment definition and form from a particular angle of vision and through a special filter of values and beliefs"*

These theories conceptualize human-nature interaction where the human is an active participant in seeking, processing and making judgments about the landscape that generates affinity or attachment to a particular place manifested by a unique set of belief of norms.

Translating this interaction of human and nature within bioregionalism, these theories imply that societal outcomes when managing ecosystems are not dictated by the biophysical process, but rather are guided by the spatial organization of the landscape built upon ecosystem sciences in such a way that it fulfills both social and biophysical objectives. As a result of this developmental process, this implies that "sense of place" includes or integrates ecological science and landscape values. Planning considered as a process "founded on the need to deliver human experience" underlines the complexity of negotiating public values and meanings (Knopf 1983:229). The implications of ignoring this experience may include influencing the way people react or behave, either positively or negatively in that place setting. As bioregionalism stresses the notion of people knowing the "place" in which they live, it is crucial to understand the process of how a place is developed from the human interaction with biophysical components.

The bioregional planning approach that is conveyed in this article aims to provide an integrated framework that will relate ecological imperatives alongside the social systems. While discussion on bioregional planning as a framework for land use planning, conservation and social reorganization (see discussion in Brunckhorst 2002; Miller 1996) is beyond the scope of this paper, we acknowledge that the framework shares a common ground among the various definitions, that is, bioregional planning recognizes both the natural environment and human societies as dynamic components of the landscape. Consequently, the implication for bioregional planning is that it is an integrated ecosystem management system, where plans for conservation and maintenance of ecological integrity depend on sustaining human processes and vice-versa through co-operative decision-making (Berkes and Folke 1998; Bunch et al 2011; Cumming 2011).

The foundation of bioregional theory amalgamates human and ecological needs as applied in the ecological land use planning paradigm (McHarg 1995). However, bioregions are also perceived as a place, acknowledging the influence of collective public vision in the development of place and accordingly desire to maintain the ecosystem (Brunckhorst 2001). The following section elaborates further on the association between a sense of place as a social process and how this process influences social actions of conservation and development policies. The two main thematic notions of bioregions as a transformation of place, and environmental stewardship which empowers communities, are deconstructed and a conceptual model is proposed that illustrates the role of people-place collaboration in achieving social and ecological sustainability within the context of bioregionalism.

3.4 Sense of Place Nurturing and Empowering Positive Landscape Change

Environmental stewardship is one of the core principles of community planning articulated in bioregionalism as people who live in a specific place, consciously develop their own idea and way of living in relation to that particular place. As outlined earlier, disintegration of people and place in the rational planning approaches disempowers community members from their civic role and responsibility towards the protection of their living environment. In contrast it is apparent that developing the competency of community-based-decision-making is founded on residential understanding of local resources availability. Bioregionalism under these circumstances becomes a decentralized planning exercise, underscoring the importance of economic and political decision-making to be delegated at a local level, which inherently gives rise to personal and community empowerment (Harris 1994). Moreover, community empowerment is translated into active participation in decision-making that fosters a shared learning process – a quality legitimated by the interaction between experiential and technical knowledge (Aberley 1993; Diffendefer and Birch 1997).

Such mobilization of empowerment is determined importantly by understanding the connection of humans with their natural world and stewardship of the land. The emphasis on consideration of human connection and values in planning potentially can be the turning point for more directive actions towards a resilient social-ecological system. Concurring with bioregional thinking, it advocates the re-envisioning of people-place relationship translated into "repairing…the damage done to natural systems, and recreating human cultures capable of flourishing in an ecologically sustainable manner through time" (Plant and Plant 1990 cited in DePrez 1997:43). Human culture in this sense is parallel to the land ethics that Aldo Leopold espoused, which works toward intensifying the sense of care, commitment and concern of how the place should be. He eloquently suggests that in developing a land ethic, the role of humanity is transformed from conqueror of ecological system to an egalitarian view that a human is "just plain member and citizen of it" (Leopold 1949:240). He further asserts that culture which then drives societal action can be assessed in relation to one's connection or association to the natural world:

> *"A thing is right when it tends to maintain the integrity, stability, and beauty of biotic community, it is wrong when it tends otherwise"* (Leopold 1949:266).

One of his supporters, Worrell and Appleby (2000:269), suggest that environmental stewardship is a form of land ethic, defining it as a deeply held moral obligation interpreted into actions of "responsible use (including conservation) of natural resources in a way that takes full and balanced account of the interests of society (and) future generations … as well as private needs, and accepts significant answerability to society". Considering that society must confront multifaceted issues related to land management, a compelling question arises. In what way are social actions directed towards achieving social, economic and ecological sustainability? It has been suggested that the land ethic should provide a conceptual foundation for environmental stewardship that can guide the action and response of society towards addressing the threat of ecosystem degradation and resources depletion (Knight 1996). This segment will articulate and characterize certain qualities promoted by ethical social action that would qualify as environmental stewardship, which is initiated from planning and conservation decisions.

The majority of research into planning, resource management, environment and behaviour have made connections between place-based values and stewardship, although in each case it has been explored within its own paradigm. Studies in landscape and urban planning for example, have explored the role of local resident attachment to rural and urban landscapes in determining their motivation for stewardship and land protection (Lokocz et al 2011; Walker and Ryan 2008). These studies have found strong connections between place attachment and stewardship engagement. This quality is manifested through several forms of supportive attitude towards conservation strategies that promote ecological stability. Inasmuch, this presents evidence that residents are more concerned about their connection to place by sustaining the local economic and landscape character. Studies have shown that social actions through several mechanisms in development planning directly contribute to social embeddedness in a physical context. Cantrill (1998) indicates that "sense of place" constitutes a major role in influencing individual capacity and involvement in environmental advocacy for sustainable resource policies. A study by Lerner (2005) examined how attachment to a place empowered a community for a positive change against a local contamination issue. The study concluded how sense of place defines us and the environment through the process of the creation of 'change maker', a person that is empowered to make positive changes in regards to local land use issues through active participation. Kruger and Shannon (2000:475) assert that citizens who developed awareness of their local context seem to "grasp the opportunity to create knowledge, benefits, and new opportunities for social action". These studies exhibit that an ability to practice attitudes which heighten the protection of ecosystems are underlined by an awareness of place-based knowledge.

Drawing on literature in environmental psychology and behaviour, volunteer motivation for engaging in stewardship programs have been demonstrated to depend on whether they can view it as a process of social learning, care-taking of the environment, as well as developing sense of belonging to that place, or not (Bramston et al 2010). Over and above people-place relationship theory, other studies have explored this concept through the lens of community attachment – how socially based attachment determines attitudes about local environmental issues (Brehm et al 2006; Stewart et al 2004). This line of research distinguishes between socially based bonding relating to physical attachment, and the emphasis placed on community-level attachment on environmental concerns.

As the people-place connection is inextricably embedded in the ecosystem context, previous studies suggest emotional bonding with the place can mediate the way people respond and react to ecosystem change through several mechanisms. For example, people who exhibit a strong sense of place demonstrate more commitment to problem solving and are more likely to react to environmental issues. This is a predictor of a resilient characteristic of dynamic landscape change (Burley et al 2007; Kaltenborn and Bjerke, 2002; Lai and Kreuter 2012). These studies have suggested that the role of communities within themselves can make clear how the policy should be oriented towards their needs. Pertinent to that, resident acceptance of proposed landscape changes are inclined to legitimize and enhance their meaning of place in the planning process (Stewart et al 2004). This finding for example, was underlined by Steadman (2002) where place-based values are incorporated into the decision-making process, thereby creating a protective behaviour that seeks to maintain and enhance values attributed to place. Similarly, Vaske and Kobkrin (2001) found that local attachment to natural resources could be a valuable mechanism to predict whether an individual acts in an environmentally responsible manner (or not). These studies, when applied within various fields related to environmental policy-making, have demonstrated that the people-place connection and community attachment have played a significant role in guiding specific social actor behavioural responses, either positively or negatively, to environmental decision-making.

4. Synthesis and Prospective Future Research

Based on a review of the literature mentioned above, land use planning, resource and biodiversity conservation can be observed as activities that manage biophysical components, and also manage the creation or destruction of human territorial regions, which are composed of complex values, interactions and meanings. Congruent with the development of system and complexity theory, more models are being developed to assess the human impact on landscape change (see for example in Hersperger et al 2010).These include environmental aspects (e.g., Wu et al 2008), economic (e.g., Irwin and Geoghegan 2001), political and institutional influences (e.g., Clement et al 2006), in addition to attitudinal considerations (e.g., Karali et al 2011). While most of these factors largely involve definitive and measurable indicators, the less perceptible gauge of human well-being or satisfaction, the attachment to place, has received little attention. This type of value system is seen as less defensible as it is regarded as far more difficult to measure, with an "unseen" physical impact in managing sustainable land use practices. In other words, "it is easier to oppose land uses when there is hard evidence that these practices will have tangible, measurable, objective and widespread impacts" (Stedman 2005:121).

Although sense of place demonstrates ethical-based attitudes in protecting the place, the different conception of place in relation to those actors who are the planners that influence the representation of place remains unclear. Stedman (2005) asserts that place attachment can be a catalyst determining the choice and activities in land use outcomes. In his study, these differences were observed whereby the impact of shoreline development on sense of place between two groups of property owners was assessed. The end result revealed that the degree of lakeshore development significantly influenced the residents' considerations about their lake. While the property owners on lightly developed lake shores associated their sense of place with that of a pristine, natural-based setting that is peaceful, this view for the residents on highly developed lake shores was held to a far lesser extent. The residents of highly developed lake shores were more likely to consider their place as residential-suburbia, packed with related urban services and recreational opportunities with consequential pollution problems. In a similar manner, a study of whitewater recreationists in California found that individuals who believed their personal identity was shaped by their natural resources held different views and attitudes of how the place should be managed compared to individuals that valued the resource more so as a functional setting (Bricker 1998). The discrepancies between the different individuals' values of place demonstrate that human cognition has a pivotal and measurable impact on future land use pattern and consequent impact on associated resources. Negotiating the meaning of place by various social actors inevitably implies a different direction for future actions. Although some studies indicate that while an attachment to a place substantially expresses a strong support to maintain the setting, an understanding of the way in which the place can be perceived by various actors may imply a different course of action that further determines the future of the spatial pattern. Hence, the repositioning of our sense of place through bio-regional thinking is imperative, underlining its importance to nurture and empower human culture towards a positive landscape change.

Figure 2 proposes a conceptual model linking sense of place with social and ecological sustainability. Drawing upon this conceptual framework, the compelling question arises for further study; How are land use decisions rendered by the negotiation of the actors' values, which then in turn shape the land use patterns and ecosystem services that will further be enjoyed by the communities at large? This framework illustrates sense of place as a concept of a social-ecological process that helps make conservation and development policies viable by acknowledging the values and meanings of humans. It captures the idea that ecosystem functioning evolves as a result of human understanding of the place across social structure and institutions; specifically, it is manifested in an amalgamation of social attitudes and behaviors in influencing land use outcomes. This article argues that individual and community empowerment is developed from the connection to the place within which they are embedded, and this serves as a basis for developing an ethical and moral responsibility for actions mobilized by stewardship to the land. It is contended that this framework could assist planning actors in understanding local values through improvised planning processes that encourage collaborative, community-led decision-making.

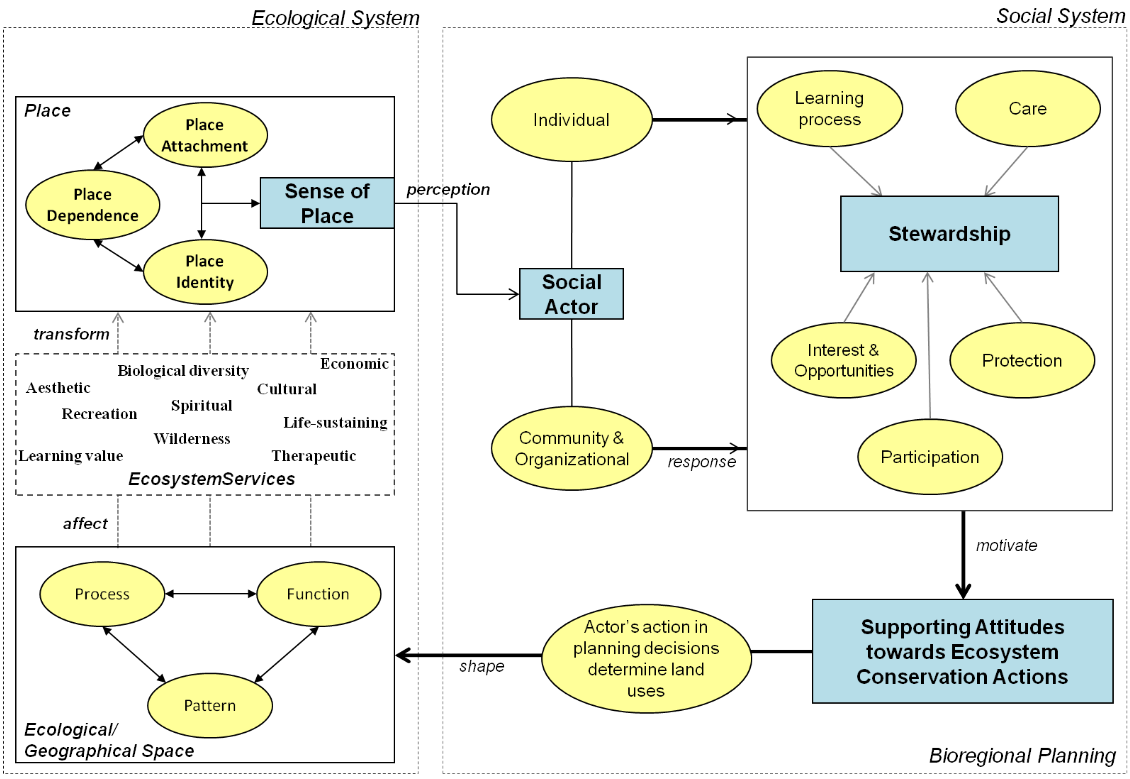

Figure 2. Conceptual model linking the core premise that the people-place relationship fulfills an important role in achieving social and ecological sustainability.

5. Conclusion

As stressed in this article, bioregional planning envisions the role of people-place relationship being in its core foundation to characterize specific emergence of social behavior in planning decisions. This re-positions the human dimension in integrated ecosystem management, suggesting an alternative path to the sustainability of socio-ecological systems especially in dealing with the uncertain future of our plans today. The evolution of an ecosystem is partly but crucially determined by what we identify as important for the next generation to enjoy including the ecosystem services that we are experiencing now. In conclusion, a sense of place is a concept that people use to imagine themselves into the ecological system and so plays a powerful role in influencing and distinguishing actions across social actors in land management. The conceptual model proposed provides a framework to assess the influence of sense of place ecological system evolution.

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An Analysis of Thermal Comfort and Energy Consumption within Public Primary Schools in Egypt

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Abstract. Schools constitute the most suitable sector of building for the application of indoor thermal comfort quality as they represent a broad sector of construction. Thermal comfort plays a major role in the educational building sector, especially in hot-arid climate. It has a big impact on building interior temperature as well as on energy consumption. The present study is primarily an attempt to assess the existing indoor thermal comfort status as well as energy consumption in Egyptian public primary school building. To meet this objective, a methodological procedure has been followed; a field study was conducted in a school building that are designed based on natural ventilation and air movement through ceiling fans to assess the indoor thermal conditions based on adaptive standard comfort (ASC) model. In addition, electrical utility bills have been collected. Then, a dynamic building energy simulation model was carried out by using, DesignBuilder software for examining indoor comfort conditions as well as the energy consumption of a typical school building in Egypt. Findings revealed that lighting sources represent the largest proportion of energy consumption. In terms of indoor thermal comfort, results indicate that a higher level of thermal discomfort within the primary public school classrooms and the pupils stay more than 36.5% of their time daily in classrooms with thermal stress conditions.

Keywords: Thermal comfort; energy consumption; school building; simulation; naturally ventilated

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1. Introduction

1.1. Background

With increased global concerns on climate change caused by anthropogenic greenhouse gas emissions (Taleb and Sharples, 2011), the need for innovative spaces which can provide indoor thermal comfort and energy efficiency is also increasing.

Predictions published by the Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change and Working Group III, 2000) indicate an increase in global average surface temperature in different scenario ranges of 1.1–2.9℃ to 2.4–6.4℃ from a 1990s baseline towards the end of the 21st century. Across Egypt, which is the focus of this study, air temperature has already increased between 1℃ and 2℃ since 1970 and is expected to increase another 4℃ by 2100 as the special Report of Emission Scenario states, SRES, A1F (Nakicenovic and Swart, 2000). In conjunction with a raised awareness for climate change, energy consumption in buildings is taking central attention in Egypt on the public triggered by the electricity supply shortage in 2012 and 2013 as buildings sector consumes about 42% of energy (Hossein Rasazi et al., 2010). Additionally, buildings accounted for 33% of the carbon dioxide which is the primary greenhouse gas associated with global climate change (Mahmoud, 2011a).

Furthermore, thermal comfort plays a major role in buildings sector, especially in hot-arid climate. It has a big impact on building interior temperature as well as on the energy consumption. According to (Lawal and Ojo, 2011), thermal behaviour of a building is determined by the extent of thermal controls provided in the building and the existing outdoor conditions. Therefore, the thermal performance of the building envelope is one of the most important determinates of the building's energy consumption.

This study focuses on school buildings as they represent a significant part of the building stock, and also noteworthy part of total energy use (Zeiler and Boxem, 2013). Therefore, this research gives an insight into thermal comfort and energy consumption for public primary school classrooms in the Egypt through filed investigation and a series of building simulations. It is known that the primary school education system deals with pupils in such a sensitive yet promising age. This is as an important point that children are impressionable and the comfort of their environment is an important aspect of quality learning. In addition, children are more vulnerable than adults to environmental pollutants (Suk et al., 2003). Over the past several decades, research has established relationships between the classroom environment and students outcomes and identified determinates of learning environment (Puteh et al., 2012).

In Egypt, which is the focus of this study, it is reported that there are about 15600 schools all over the country with 37.6% of all pre-university education (Ministry of Education, 2012). This demand had considerably increased after the 1992 earthquake that devastated a considerable number of schools (Gado and Mohamed, 2009a). In response, the Egyptian government established the General Authority of Educational Buildings (GAEB) to design new schools around the country. These designs relied on an infiltration air of cross-ventilation with ceiling fans to achieve thermal comfort within the classrooms. GAEB uses the same prototype designs to establish schools across the various climatic conditions in many regions of Egypt without consideration to the significant variation in all climatic conditions. This led to uncomfortable interior conditions within the classrooms which span from heat stress, lack of adequate ventilation, glare to exposure to excess solar radiation.

It is evident that a large body of social science and environment-behavior research was conducted in school buildings in the 1960s and 1970s (Gado and Mohamed, 2009a). However, insufficient research has addressed indoor environmental settings with respect to thermal comfort and energy consumption conditions in school buildings. It should be pointed that thermal comfort studies typically focus primarily on occupants in residential buildings and offices where groups of occupiers often share work, which facilitates easier surveying by research investigators (Ali Ahmed, 2012; Sayed et al., 2013). Therefore, the thermal comfort is still one of the most important issues should be considered in government primary schools buildings as it has direct negative impact on teaching and learning as well as the potential for energy conservation via careful temperature control with the classrooms.

1.2. Climate context

In preliminary, Egypt is located between 22°N to 31° 37 ′N latitude and 24° 57′E to 35°45′E longitude with an area of approximately 1,000,000 Km^2 (Mahmoud, 2011a). Egypt has a significant variation in the climatic conditions. The Housing and Building Research Centre (HBRC) divides the country into eight different climatic design regions as reported by (Sayed et al., 2013) (see Fig. 1). According to Koeppen's climate classification (Kottek et al., 2006), Egypt experiences the 'hot desert climate type' (BWh) in the southern and central parts of the country and the 'hot steppe climate type' (BSh) along the coast. Most parts of Egypt are occupied by the Sahara desert, which represents the most extensive arid area on the planet. In general, Egypt possesses a hot-arid climate throughout the year.

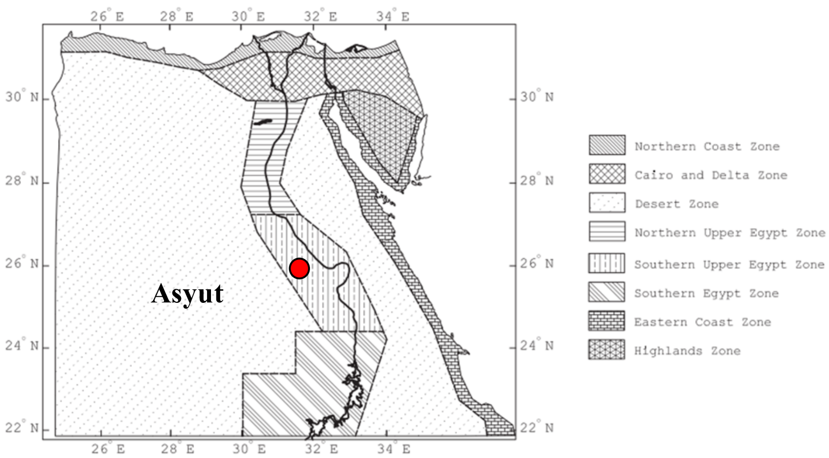

Figure 1. Classification of climatic zones in Egypt according to HBRC (Mahmoud 2011b).

3.1. Aims and objective

In the light of aforementioned, a design procedure to understand the existing situation of indoor comfort conditions in public primary school buildings is desirable. The primary objective of this study is to assess thermal comfort conditions within recent government primary schools in Egypt.

To this end, a field measurement exercise was conducted in the selected school building, followed by computer modeling work using 'DesignBuilder' software to simulate thermal performance and energy consumption of the school building. Subsequently, the calculated values from field measurement and the simulation results were compared for validation purposes.

2. Methodology

2.1. Field investigations

2.1.1. The case study (visual survey)

Experimental investigation of thermal comfort conditions within public primary schools that are designed based on natural ventilation (infiltration) and air movement within the classrooms by ceiling fans were carried in Assiut city (27°3′ N; 31°15′E) as seen in Fig. (1), which located northeast of the southern Upper Egypt zone (Ali Ahmed, 2012). The field study was conducted in three naturally ventilated classrooms from 29th to 31th October, 2013 at Assiut prototype distinct language school that was built in the year 2009. This school mainly belongs to the General Authority of Educational Buildings (GAEB) and has been designed according to one of the prototype architectural system that has been carbon-copied all over the country. All the studied classrooms based on natural ventilation (infiltration) and air movement within the classrooms through ceiling fans. Windows are single glazed and poorly constructed with very high levels of air permeability at both sides (1.5x1.2m), window to wall ratio reaching 32%. There is no solar protection in the windows, only the roof edge slightly mitigates the sunshine. The occupancy rate of this school is 1.1m^2 for each pupil (the USA ratio is 2.15m^2).

2.1.2. Measurements and data recording

In this field study, Thermal Comfort Datalogger-INNOVA 1221, shown in Fig. (2), was used for measuring and recording the classroom indoor environmental parameters such as operative temperature, relative humidity and air velocity during the school working hours when the classrooms are being fully occupied with the pupils to evaluate thermal comfort conditions. The INNOVA 1221 is a black box (138mm*285mm*300mm) built up modularly with up to four input modules. The data logger is supplied is supplied with a battery pack for use in the field Three external sensors (with measuring accuracy ±0.1 ºC) were connected to the device which was placed in front of classroom beside the board in order to not to interfere with ongoing teaching activities. The classroom furniture is arranged in three row perpendicular to the whiteboard's wall (see in Fig. 3).

The data values were measured and recorded every minute and the average of each 15 minutes was determined and is presented in the results section. While, outdoor Asyut climate data were obtained from the meteorological records of the nearest regional weather station (WMO 62392) for the same period in addition to a Mobile Weather station to measure the outdoor temperature in the school yard. Moreover, electricity utility bills has been collected from Egyptian Ministry of Electricity for the whole year 2013 as well as information about occupant density and lighting sources.

2.2. Modeling and simulation

The analysis of this paper is mainly concerned with assessing the current status of internal building comfort condition, according to ASHRAE standard 55 (ASHRAE, 2010a), as well as energy consumption within public primary schools, which belong to GAEB in Egypt. A typical primary school building was selected to act as a case study for this research, this school has a total land area of 3168.37 m^2, is a five-store height. Each store consists of 5 classrooms with the school total of 24 classrooms. Modelling and simulations were carried out using the dynamic thermal simulations tool, DesignBuilder (DB) in its third version (V.3.4.0.033), which is based on the state-of-the-art building performance simulation software entitled EnergyPlus. The following sections define the different configurations and parameters of the case study.

For the simulations, a model of a typical school building in Assiut was applied to address indoor thermal comfort conditions within naturally ventilated classrooms and predict energy consumption for the base model, which constitutes the most prototype architectural design that has been carbon-copied all over the country.

Figure 2. Thermal comfort INNOVA 1221.

Figure 3. Field study inside class (A) shows the disk's distribution.

2.2.1. Base model development

Geometries of the case study was constructed in DesignBuilder based on the site plan survey as well as the construction drawings supported by GAEB. A three-dimensional DesignBuilder model for the case study was firstly developed (see Fig.4). Additionally, each space in the buildings was drawn as a thermal zone according to its function and each was given a name.

The simulation is based on 'real' hourly weather data, and taking into account solar gain through windows, as well as heat conduction and convection between zones of different temperatures. For this study, the following properties were implemented in DesignBuilder:

a) *Construction material*

The construction materials used are conventional according to the Egyptian Code for Buildings. Exterior walls are made of 25 cm red brick with an interior finish of 2.5 cm thermal plaster and paint (acrylic based for contracting and expanding). Interior partitions are of 12 cm thick red brick as well as 4 to 5 cm thickness of cement plaster and paint for both sides. Floors are suspended with 10 cm finishing thickness. Slabs are made from concrete of 12 cm thick according to the spans and structure system. The specifications for construction materials used in the simulation are listed in Table 1, and the section for the aforementioned walls are shown in Fig. 5.

b) *Glazing type and lighting*

According to Mahdy and Nikolopoulou (Mahdy and Nikolopoulou, 2014), there are four main categories commonly used in Egypt, mentioned and specified in (EREC), as shown in Table 2. In simulations, windows are aluminium frames with 6 mm single clear layer glazing. The window to wall ratio (WWR) is 32 %. On the other hand, each classroom has four groups of artificial lighting with three 1200 mm T8 lamps.

c) *Activities and schedule*

According to ASHRAE standard 55 (ASHRAE, 2010a), metabolic rate of seated activity = 1 met which equal 60 w/m^2, and so metabolic rate per person = 60 x 1.8=108 W/per according to ASHRAE standard 55 (ASHRAE, 2010a). In terms of vacations and working days, a combined schedule was applied to the simulation based on The Egyptian school year which starts at 15th September and ends on 30th June.

d) *HVAC and infiltration*

All classrooms are naturally ventilated with two ceiling fans in each classroom for air movement. Windows are single glazed and poorly constructed with very high levels of air permeability at both sides (1.5x1.2m), window to wall ratio reaching 32%. There is no solar protection in the windows, only the roof edge slightly mitigates the sunshine. Windows are operable from 8:00 am till 3:00 pm so, the infiltration rate suggested to be 0.5*ach/h*.

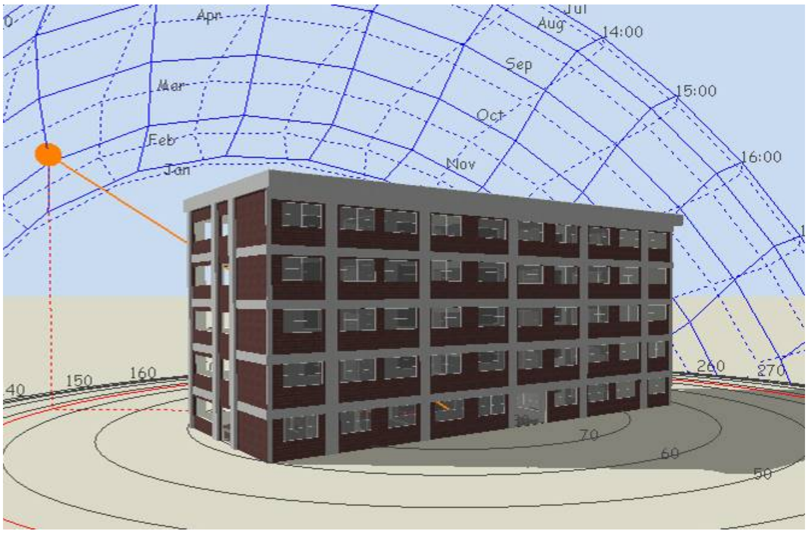

Figure 4. Reference case model in DesignBuilder.

2.2.2. Simulation & validation of the base model

Model validation is an essential task to ensure that the architectural, mechanical and electrical systems. (Oberkampf and Trucano, 2002) defined the verification and validation of computer simulation as below: "*Validation is the assessment of the accuracy of a computational simulation by comparison with experimental data*". Kaplan and Canner (Rahman et al., 2010) made recommendations for the allowable difference between predicted and measured (actual) data. For instance, the prediction of energy use is considered satisfactory when the difference is within 5% on a monthly basis for internal loads such as lighting, appliances or domestic hot water system. However, the acceptable difference may increase up to 15–25% monthly and 25–35% daily for the simulation of environmental parameters. In this computational simulation process, three parameters were considered for base model validation. They are internal average hourly temperature, average hourly relative humidity and monthly energy consumption.

Table 1. Physical characteristics of base model building.

Material	Thick. mm	Density kg/m^3	Conductivity W/m.K	Specific heat J/kg.K
External wall from outside to inside (*U-value=1.58 W/m^2.K*)				
Plaster (light)	25	2300	1.3	840
Mortar	20	2800	0.88	896
Brick	250	1500	0.85	840

Internal partitions (*U-value= 1.64 $W/m^2.K$*)				
Plaster (light)	25	2300	1.3	840
Mortar	20	2800	0.88	896
Brick	120	1500	0.85	840
Mortar	20	2800	0.88	896
Plaster (light)	25	2300	1.3	840
Intermediate floors (*U-value= 1.14 $W/m^2.K$*)				
Ceramic tiles	25			
Mortar	20	2800	0.88	896
Sand brick	60	2200	1.83	712
Reinforced concrete	120	2300	1.9	840
Mortar	20	2800	0.88	896
Plaster (light)	25	2300	1.3	840
Roof (*U-value= 1.92 $W/m^2.K$*)				
Mosaic tiles	30	2100	1.4	800
Mortar	20	2800	0.88	896
Sand brick	60	2200	1.83	712
Reinforced concrete	120	2300	1.9	840
Mortar	20	2800	0.88	896
Plaster (light)	25	2300	1.3	840

Table 2. Used glass specifications.

Name	**Category**	**SHGC***	**LT****	**U-value *$W/m^2.K$***
Clear 6.4mm	Single	0.71	0.65	5.76
Clear reflective 6.4mm-(stainless steel cover 8%)	Single reflective	0.18	0.06	5.36
Clear 3.2mm Transparent/Transparent (6.0mmair)	Double	0.66	0.59	3.71
Clear reflective 6.4mm Transparent (stainless steel cover 8%)/ transparent-(6.0mmair)	Double reflective	0.13	0.05	2.66

*Solar heat gain coefficient
** Light transmission

a) Outer surface b) Inner surface

Figure 5. Wall sections used, (a) exterior wall and (b) internal wall/partitions.

3. Results and discussion

3.1. Measured thermal condition

The thermal comfort evaluation stage in the presented study is determined by three methods which are:

- Using the PMV and PPD values inside the classrooms in accordance with ISO 7730 (ISO Standard 7730, 2005) specifications which was originally developed by Fanger in 1970 on the basic of climate chamber experiments
- Using the Adaptive Comfort Standard (ACS) for naturally ventilated buildings which were employed by ASHRAE standard 55 (ASHRAE, 2010b).

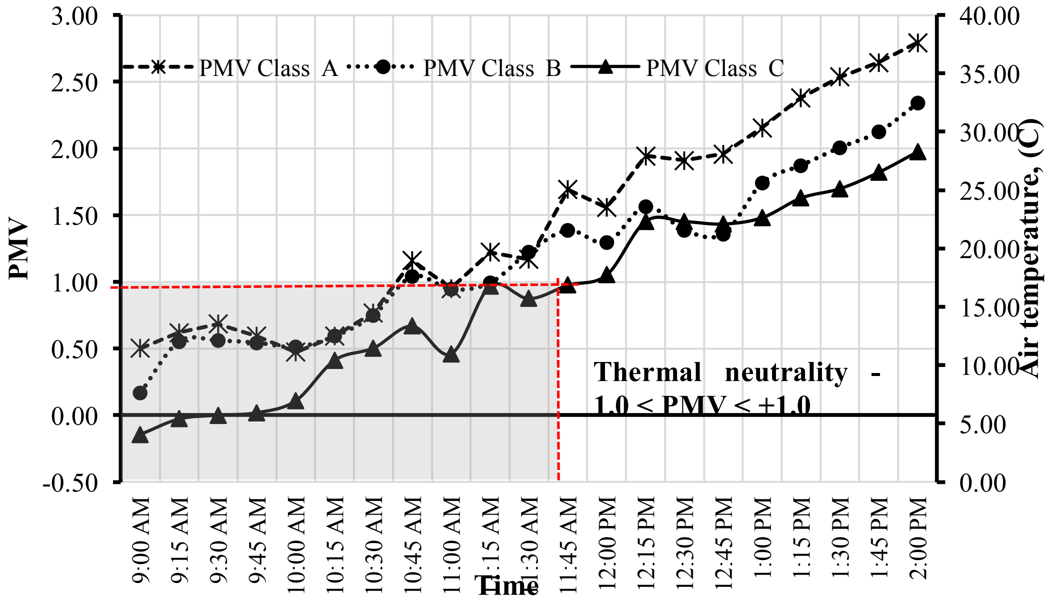

Figure 6. Indoor air temperature against PMV.

According to ISO 7730 (ISO Standard 7730, 2005) specifications, the acceptable thermal environment for a PMV lies between -1 and +1 and the PPD is below 20%. The PPD is related to the PMV and it is based on the assumption that people voting -3,-2, +2 or +3 are dissatisfied. PMV for case studies started at -0.14 value and raised until 2.8 value at the end of school day, further analysis showed at the afternoon the PMV value increases the comfort limit as shown in Fig. 6. The average PMV and PPD across the classrooms were 1.17 and 38.86%, respectively which indicate a high level of thermal discomfort in the classrooms. The same trend that was predicted by Gado and Mohamed (Gado and Mohamed, 2009b).

In the ACS, the mean monthly outdoor air temperature determines the acceptable indoor air temperature. This relationship is expressed by the following formula:

$$T_{com} = 0.31\,(T_{out}) + 17.8$$

Where T_{com} is the optimum comfort operative temperature in °C and T_{out} is the mean monthly outdoor air temperature in °C. Thus, in this context the acceptability ratio of thermal environment decreases less than 80% when the indoor operative temperature exceeds 29.5°C. The measured data clearly show that there has been a steady increase of operative temperature in the measurement within the classrooms ranged from 25.5ºC to 34.5ºC during that day time. As depicted from Fig. 7, the internal classroom temperature is raised by 7 ºC. According to the results of (Humphreys, 1977) this level of increase well led to discomfort condition for the pupils. This might be due to the fact that children are sent to the schools wearing relatively warm clothes in the relatively cool morning than required for the range of temperature variation during the school day. Clearly from the figure, the internal air temperature profiles across the three cases studied are within the comfort limit until noon time. While afternoon time, the results indicate that the internal air operative temperature across the three classrooms exceeded the comfort limit which means that pupils are in discomfort for about 39.86% of the time they spent in school.

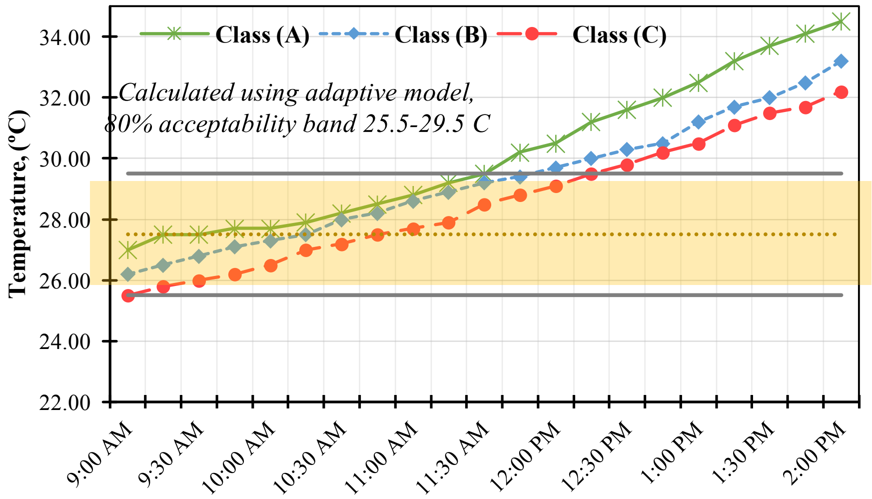

Figure 7. Indoor operative temperature profiles with (ACS) comfort zone limit.

3.2. Calibration test

As mentioned earlier, in this computational simulation process, three parameters were considered for base model validation. They are internal average hourly temperature, average hourly relative humidity and monthly energy consumption. Figure 8 shows detailed comparisons of the indoor air temperature, outdoor air temperature during selected day from field study.

It can be clearly seen that the predictive simulated results tend to be underestimated the experimental results. As Fig. 7 displays the highest indoor air temperature during the three days was recorded as 32.2°C and the lowest indoor temperature as 25.5°C, while DesignBuilder simulation showed the highest indoor air temperature as 32.5°C and the lowest indoor temperature as 24.8°C. On the other hand, the highest outdoor air temperature during field study was 34.5°C, while DB simulation showed the highest outdoor air temperature was 35.2°C. In conclusion, the measured data varies within 6.7% of the simulated data. The discrepancies between the measured and predicted results might be due to that, in the real building, there were numerous infiltration airflows paths which allow the indoor heat to dissipated. However, in DB model the infiltration rate was fixed and the values could be lower than that of the real buildings. Hence, less heat dissipation in the DB model led to higher prediction of the indoor heat gain.

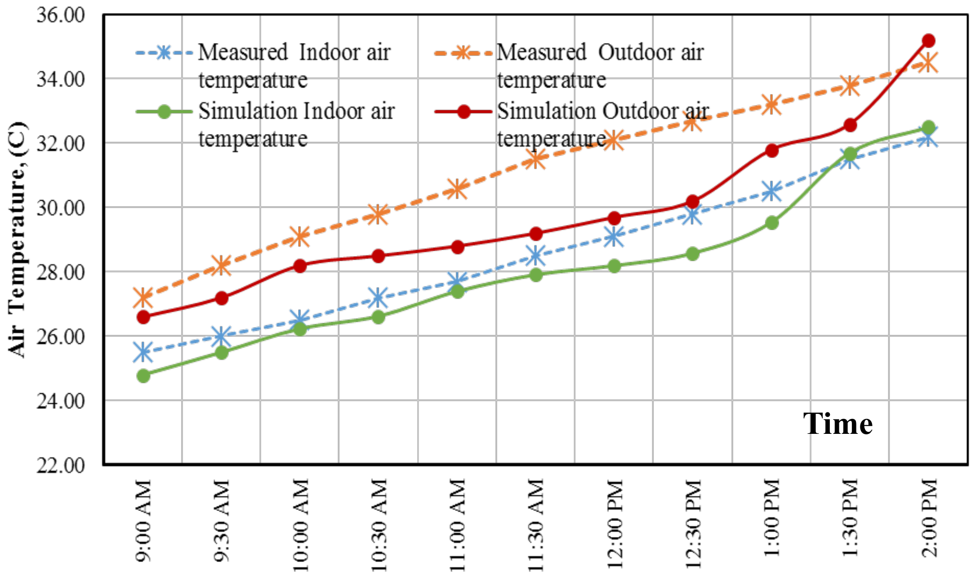

Figure 8. Measured vs. simulated internal average hourly indoor air temperature and average hourly outdoor air temperature.

3.3. Energy use

Each zone of the building was physically investigated with the assistance of the building's operation in order to obtain information and data on the building lighting, equipment and occupancy for the purpose of knowing details of thermal characteristics of building envelope. Moreover, electricity utility bills for the whole year 2013 has been collected. For the financial analysis, the cost of the energy consumption was calculated in Egyptian pound (EGP), using the electricity tariff by the Egyptian Ministry of Electricity and Energy for the governmental sector, which is referred to as operation cost. Next, the energy use within the building was simulated for a whole year, using real climatic data. It is found from Fig. 8 that the collected data of energy is within 9% of the simulated energy consumption. This demonstrates that the DB predictions are in good agreement with the data collected.

According to the simulation and collected results the annual electricity consumption for the building was 13019 kW per year (9227.27 EGP per year). This means that the building is consuming 1.5 kWh/m^2/year of electrical energy. Based on simulations, lighting sources consume the largest amount of total consumption. Fig. 9 shows that the electricity consumption in summer months is slightly higher than the winter months, because of appliances auxiliary system (two ceiling fans in each classroom as they are operating all over the school day).

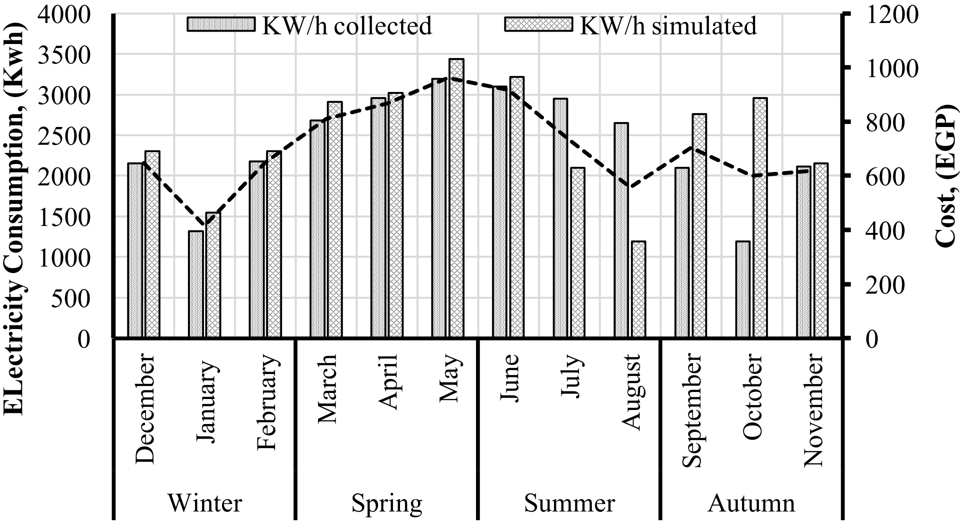

Figure 9. Comparison between averaged electricity bills and energy simulation.

3.4. Comfort analysis

As a result of model validation, a simulation using DB software was applied to get values of indoor air temperature within school day and outside air temperature of Assiut climate zone through the school year. Consequently, comfort limit conditions were determined based on ACS model which were employed by ASHRAE standard 55. All material and construction details, as discussed previously, have been applied to the simulation model. On analysing the hourly climatic data of Asyut city, it is clearly seen from the displayed Fig. 10 that that the predictive indoor air temperature exceed the adequate level of comfort during October (the first of 20 days and the rest of month after noon time), the last half of April and May entirely represent about of 32.29% of school year contrary of 7.98% of discomfort conditions during morning hours as indoor air temperature declined the minimum limit of adequate comfort in last December and January. On the other hand, 59.73% of occupied time the predictive indoor air temperature expected to fall within comfort limit.

In terms of heat gains which refer to flows through the fabric due to the air temperature difference between inside and outside. Fig. 11 displays the main sources of heat gain within classroom during school day. As depicted from the figure, solar gains from exterior windows, which increased around noon hours as a result of increasing of solar radiation incident amount, are the largest source of heat followed by the occupants and lighting. While, ceiling and internal walls represent a small proportion of total heat gain of the building.

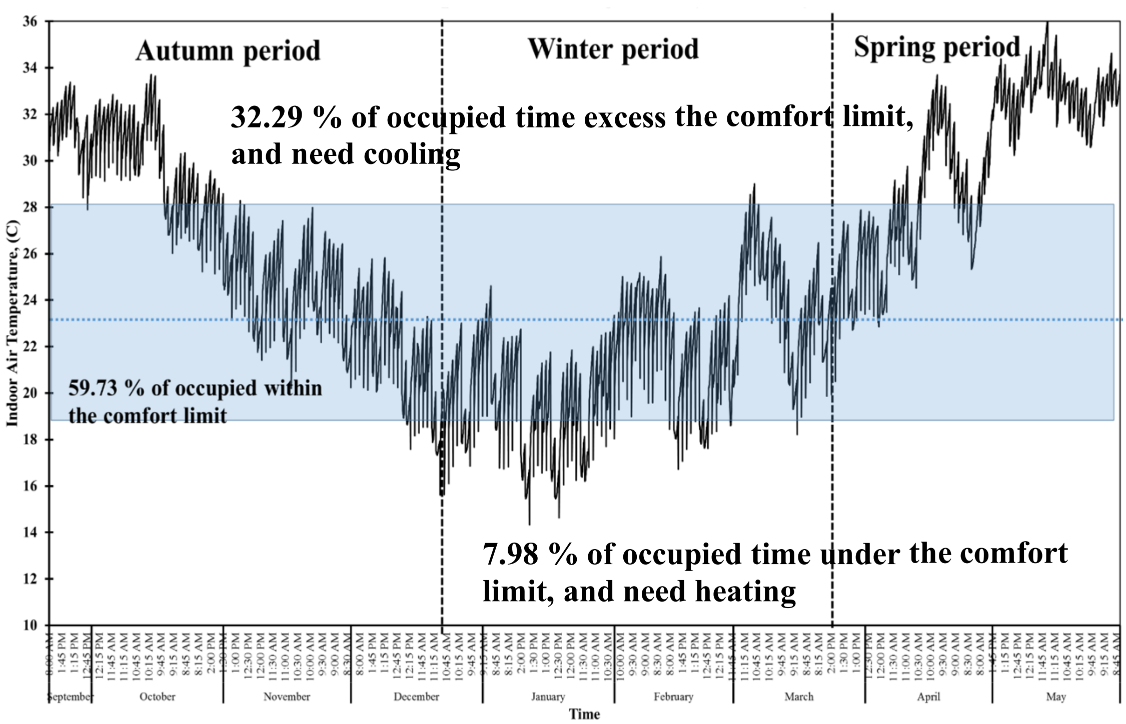

Figure 10. Indoor air during school year in occupied time in Asyut.

4. Conclusion

This study investigated the thermal comfort conditions as well as energy consumption within public primary schools that are designed based on natural ventilation (infiltration) and air movement within the classrooms by ceiling fans. The output results may assist school building designers and stakeholders in the future to improve the thermal environment conditions within the classrooms of such schools. The main achievements of this study are as follows:

- It is reasonable to conclude from this study that DesignBuilder is a satisfactory simulation package with which to assess thermal comfort conditions and predict energy consumption for public school buildings in Egypt.
- The acceptability ratio of thermal comfort calculated by (ACS) model ranges from 25.5ºC to 29.5ºC. It is expected that students spent about 59.73% within comfort conditions. In contrast, 32.29% of occupied time excess the comfort limit and fall within under-heated area. However, 7.98% fall within overheated area and need cooling.
- According to the simulation and collected results the annual electricity consumption for the building was 13019 kW per year (9227.27 EGP per year). This means that the building is consuming 1.5 kWh/m^2/year of electrical energy.

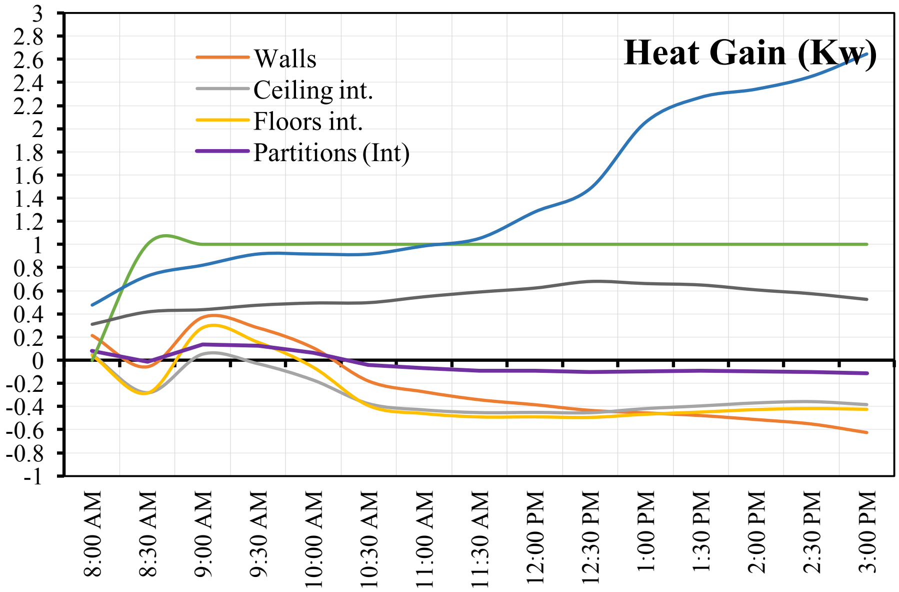

Figure 11. Heat balances in the classroom for 15 October.

In order to rehabilitate the existing government school buildings, thermal comfort wise, the study has derived the following recommendations:

- The necessity to develop new designs and guidelines to adapt the variation in climate conditions all over the country, and provide comfort conditions for occupants.
- Increase thermal efficiency of the building envelope by the use of external insulation.
- Protect all the exposed openings from direct solar continues shade on those openings.
- Support further researches on insulation materials and its behavior in local constructions.

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Environmental Sustainability Drivers: A Study on Malaysian Palm Oil Industry

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Abstract

Industrial practitioners and policy makers in the Malaysian palm oil industry are now focusing on understanding the factors that influence sustainability of palm oil supply chain network involving the fundamental principle of triple bottom line of social, environmental, and economic performance impacts of supply chain network design. In order to achieve sustainable products, an interpretive structural modelling approach method was used to better understand the drivers related to environmental sustainability reporting in the supply chain network related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers (environmental management, life cycle assessment, green labelling, GHG emissions, climate change, energy efficiency, renewable resources, water, soil and air quality and lastly waste management) and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modeling model to determine the potential drivers in environmental sustainability reporting.

Keywords: life cycle assessment, sustainability analysis, sustainability reporting, triple bottom line

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1. Introduction

With the rapidly growing world population, the demand for palm oil is increasing. Among the 17 world major oils and fats, palm oil has made impressive and sustained growth in the global market. In 2008, palm oil accounted for 54% of the world's production of oils and fats; it is projected that palm oil will become the leading oil in the world around year 2016 (Oil World 2009). Malaysia is the world's second largest producer and exporter of palm oil after Indonesia; in 2007 it produced about 15.8 million tons of palm oil. In year 2020, production is forecast to increase to 18.5 million tons (Oil World 2009). Key challenges to the palm oil industry include misconceptions on palm oil sustainability and awareness of its potential in the global vegetable oil market, consumer demands for certification of products and processes and the competitiveness on the triple bottom line performances as uncertainties to the supply network.

Sustainability of palm oil is important if this versatile crop is to become the leading vegetable oil in the world. This multipurpose vegetable oil needs to be cultivated to ensure sustainable development from the environmental, social and economic aspects. With the world's population expected to increase to 8 billion in 2028, palm oil has the potential to be the source of fats and vegetable oil to feed the people around the globe (Basiron 2006; Basiron 2009). As high demand of cheap and quality vegetable oil is needed to feed the world's growing population, building a tool to improve the performance of sustainability of the palm oil supply chain network involving real-time data is necessary in order to achieve sustainable production. In this context, all parties involved with palm oil like plantation owners, financial institutions and banks, manufacturers of palm oil products and governments play an active role to realise this win-win situation for all. Hence, the time has come for all parties to co-operate and realise a sustainable production and development of palm oil. Ideas and efforts will become futile if all parties do not take an active and responsible role towards this aim as sustainable development of palm oil requires collaboration and initiative among the stakeholders.

Sustainability is also particularly important when it comes to the production of food, especially commodities that are widely used by the global food industry. The need to produce palm oil sustainably has led to the establishment of the Round Table on Sustainable Palm Oil (RSPO 2005). This roundtable is a platform to reach mutual understanding at the international level among various palm oil stakeholders namely; oil palm growers, palm oil processors/traders, consumer goods manufacturers, retailers, investment organizations, social or development Non-Governmental Organizations and environmental or nature conservation Non-Governmental Organizations. This understanding would be translated into common actions towards achieving sustainability of palm oil production and used in its entire supply chain. The Round Table on Sustainable Palm Oil has progressed towards formulating a set of principles and criteria for sustainable production, but has yet to implement a scheme to enable sustainably produced palm oil to be certified with full traceability. It is not easy to implement such an ambitious scheme, since maintaining the chain of custody for traceability purposes will be difficult and expensive. The importance of studying these environmental, social and economic issues, such as land conversions, productivity and environmental problems were also addressed by Sustainable Agriculture Initiative Platform and Sustainable Food Lab in Short Guide to Sustainable Agriculture documents. This is particularly important with the increased awareness of the environmental, social and economic issues as one of the key factors which influence consumer's perception towards sustainability in markets such as Europe.

1.1. Sustainability SWOT Analysis of the Malaysia Palm Oil Industry

SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyse an organisation internal and external environments (Kangas et al. 2003; Kotler 1988). By identifying its strengths, weaknesses, opportunities, and threats, the organisation can build strategies upon its strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats. Strengths, weaknesses, opportunities and threats of the Malaysian palm oil industry in its present state from the SWOT analysis are presented in Figure 1.

Strengths	**Weaknesses**
-The Malaysian palm oil industry is considered the second largest in the world after Indonesia. -The Malaysian palm oil industry is greatly supported by its local government. -Palm oil itself is a resource that is used for the production of diverse products (part of agricultural diversifications). -Geographical diversifications.	-Poor performance of plantation segments. -Changes in the weather patterns worldwide can affect Malaysia's palm oil plantation and production.
Opportunities	**Threats**
-The support of the country's government and agencies to the industry in research findings. -Increasing demand of biofuels derived from palm oil and other plantation biomass which can be used as alternatives to fossil fuels such as diesel. [Palm oil gives high yields at low prices and is likely to be important in availability for future expansion for palm oil plantation.	-Shortage of labor is one of the main threats of the palm oil industry in Malaysia. -The palm oil industry in Malaysia faces significantly growing competition with other foreign producers. -The country is also experiencing lower land meeting biofuel demand].

Figure 1. SWOT Analysis for Malaysia palm oil industry (MPOB 2009; MPOC 2007; MPOB 2007).

The preliminary study of SWOT analysis was done to build understanding of the supply network in the Malaysia palm oil industry sector by carrying out semi-structured interviews. The objective was to review the literatures from academic and industrial viewpoints on the development of palm oil industry in Malaysia and categorise the findings into strengths, weaknesses, opportunities and threats and as well as in the form of semi-structured interviews. The interviews based on the semi-structured questionnaire were used to identify current practices in the Malaysian palm oil industry. This semi-structured questionnaire was designed to collect information related to the Malaysian palm oil industry. Three respondents from the Malaysia Palm Oil Board and Environmental Technology Research Centre, and the Standards and Industrial Research Institute of Malaysia (SIRIM) were interviewed. In the development of semi-structured questionnaire, key issues of interest were:

i) Topics of common issues or conflicts in the Malaysian palm oil industry;
ii) Environmental and social issues in the palm oil plantations;
iii) Environmental impacts and the sustainability initiative for sustainable palm oil production;
iv) Meeting consumer demands and requirements; and
v) Information and knowledge management throughout the supply network.

From the inputs of these interviews, data and information related to the palm oil industry corresponding to the research topic in Malaysia can be used for a better understanding of the supply network sustainability issues. The impacts to the global operations of the Malaysian palm oil industry were listed:

(i) The exposure of palm oil plantation areas to extensive impact of weather changes;
(ii) Lack of promotion on nutritional value and health benefits of palm oil and other global markets for Malaysian palm oil companies;
(iii) Research and development were conducted by government agencies rather than palm oil companies whereas the palm oil companies should continuously conduct their own researches and improve their respective research and development sectors if necessary;
(iv) Land availability for future expansion of palm oil plantations; and
(v) The challenges to enhance palm oil production and global distribution towards sustainability.

As for this research, the potential risks arising from the inherent limitations of the current supply network in the Malaysian palm oil industry were carried out. For example, with the current available data flow, any risks encountered by the plantation tier would affect the performance of the manufacturers therefore causing a negative impact on the product sustainability. In future, the potential risks identified can be useful to suppress the impacts arising under the supply network uncertainties where counter measures can be taken in order to maintain sustainability.

From the interview carried out, the responses from the officer in-charge confirmed that research studies conducted by SIRIM were focused mainly on environmental sustainability parameters which consist of:

i) Compliancy to the Environmental Management Systems;

Over the years, industrial activities which have led to environmental pollution have been gaining the attention of the Malaysian government. In order to show active involvement, the government has been promoting more environmentally friendly production by applying the Environmental Management Systems to mitigate the impacts from the pollution. In 1995, SIRIM launched the Environmental Management Systems certification scheme in line with ISO14001 in Malaysia. Protecting the environment from negative impact of industrial activities has become an important aspect that multi-nationals and export oriented companies have to portray to maintain their competitive edge in the international market.

ii) Product life cycle analysis from the environmental point of view; and

Since 2003, the SIRIM life cycle assessment team has been working on the application that is currently used to establish greenhouse gas profiles or carbon footprints aside from relating to impacts such as resource consumption, eutrophication (overly nutrient-rich water) and acidification.

iii) Eco-labelling.

Eco-label is a label which identifies overall environmental preference of a product or service within a specific product or service category based on life cycle considerations. In 1996, SIRIM launched the national eco-labelling program verifying products according to environmental criteria such as environmentally degradable, non-toxic plastic packaging material, hazardous metal-free electrical and electronic equipment, biodegradable cleaning agents and recycled paper.

The interview results were then translated using the interpretive structural modelling approach which has identified nine environmental sustainability parameters and their relationships. The findings from the analysed interactions of these parameters were used to explore potential impacts of the supply network design in the design of a sustainable industrial system.

1.2. ISO Standards

A range of standards have been developed in the last two decades to enable sustainable development (ISO 2006a). ISO 14000 standards create a systematic approach for reducing the impact on the environment due to the activities of an organization (ISO 14000). ISO 14000 standards include the ISO 14020 series for environmental labelling, ISO 14040 for Life Cycle Assessment, ISO 14064 for Green House Gases, as a few given examples. ISO 19011 provides guidelines for auditing quality and environmental management systems (ISO 19011). Figure 2 showed the examples of identified environmental sustainability drivers of life cycle stages which can be used for the proposed environmental sustainability reporting of the palm oil industry.

	Raw Material	Product Manufacturing	Transportation	Product Use	Product After Use
Environmental Sustainability Drivers					
1)Environmental Management	●	●	●		
2)Life Cycle Assessment	●	●	●	●	●
3)Green Labeling		●			
4)GHG Emissions		●	●		●
5)Climate Change	●				●
6)Energy Efficiency	●	●	●		
7)Renewable Resources	●				●
8)Water, Soil & Air Quality	●	●	●	●	●
9)Waste Management	●	●			●

Figure 2. Examples of identified environmental sustainability drivers of life cycle stages.

(i) Environmental Management

A number of palm oil mills and palm oil refineries in Malaysia have achieved certification to this ISO standard of environmental management. The standard requires organizations to assess their environmental impacts and develop an environmental policy to address them. The two specific requirements of relevance are:

- the policy includes a commitment to comply with relevant environmental legislation and regulations; and
- the policy includes a commitment to prevention of pollution.

Environmental management is an auditable standard that provides a framework for organizations to implement their environmental policies and can be verified by third party certification.

(ii) Life Cycle Assessment

In the ISO 14000 family of standards, the ISO 14040 standard provides the framework and guidance for conducting life cycle assessment (LCA). This is the "cradle-to-grave" approach for assessing the environmental profile and performance of a product from sourcing of raw materials to its final disposal after the useful life of the product. Application of this methodology to the palm oil industry would provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain from the planting of the palm oil seed to the consumption of the final processed product.

(iii) Green Labelling

Green labelling refers to a scheme which awards green label to environmental friendly products. These are products that have less environmental impacts. The purpose of labelling these products is to help consumers to identify and purchase those products that are environmentally friendly. Strong demand from the consumers for environmental labelling products will encourage more manufacturers to adopt environmental friendly policies.

(iv) Greenhouse Gas Emissions

Carbon conservation aspects need to be addressed and greenhouse gas balance and land use competition should also be included in the design of sustainable industrial systems for the palm oil industry. Additional principles should be developed for palm oil sustainability, to cover aspects related to carbon balance and preservation of carbon stocks. As reducing greenhouse gas emissions is a prominent goal for sustainable development policies, certain levels of greenhouse gas reductions based on a life cycle assessment should be developed.

(v) Climate Change

Forest conversion by plantation companies contributes to climate change. Emission of carbon dioxide known as the greenhouse gas is a cause of global warming and climatic change. The rainforests which are cleared to make place for palm oil plantations are storing huge amounts of carbon. Massive amounts of carbon are released straight into the atmosphere but the land's ability to take up carbon dioxide is also diminished with these land conversions.

(vi) Energy Efficiency

Increasing energy efficiency will help to reduce the impact of energy consumption on climate change by replacing non-renewable energy with alternative renewable and low impact energy sources.

(vii) Renewable Resources

The efficient use of renewable resources should be targeted since the use of non-renewable resources, such as fossil fuel, is not sustainable in the long term. Greenhouse gases and polluting gaseous emissions must be minimised.

(viii) Water, Soil and Air Quality

During planting, several measures must be taken to prevent soil degradation and conserve soil fertility in order to minimise soil erosion and fertilizer loss. The soil is highly susceptible to erosion during the land preparation stage preceding planting palm oil trees are unique in a way that they have higher leaf area index that allows them to have better photosynthetic efficiency to produce more oxygen to the air and absorb more carbon dioxide from the atmosphere. Water quality around palm oil plantations and processing mills must be carefully handled to avoid from the impacts of using banned herbicides and pesticides for the use to control weeds and pests. Oily sludge of palm oil mill effluent from palm oil processing mills must be treated before being discharged into water systems to avoid water supply contamination.

(ix) Waste Management
All waste must be handled, stored and disposed off correctly to avoid pollution to minimize the amount of waste produced, thus reducing environmental cost and ensuring that legislative requirements are met.

2. Materials and methods

Interpretive structural modelling was first proposed by Warfield in 1973. Interpretive structural modelling referred henceforth as ISM, is aid for modelling relational structure among the number of parameters. While dealing with large number of attributes, it gets complicated to relate them with reference to the final goal. Interpretive structural modelling can help in interpreting the decision maker's judgment about relation among the parameters. It extracts a structured model out of pool of parameters to simplify decision making process.

The major steps involved in using interpretive structural modelling are as follows:
(i) Identification of parameters
The relevant parameters to be considered in final analysis are listed in Figure 2.

(ii) Structural self-interaction matrix
Depending on the situation and parameters, a contextual relation is chosen and compared with every other parameter to decide presence and direction of chosen relationship. This generates self interaction matrix.

(iii) Reachability matrix
From the self-interaction matrix, the relational indicators are converted in to binary digits 0 and 1 to get a square matrix, called reachability matrix. Simple transitivity check is done as, if parameter A relates to B and B relates C then A relates to C. This helps in extracting a consistent model from the set of parameters. Summations of row indicate driving power of the parameters and summations of column indicate dependence. Higher dependence rank and lower driver rank indicates dependent parameters, whereas lower dependence rank and higher driver rank indicate independent parameters. Lower dependence and driver rank indicate autonomous parameter, whereas higher dependence and driver rank indicate linked parameters.

(iv) Level partition
From reachability matrix, for each parameter, reachability set and antecedent sets are derived. Reachability set contains parameter itself and other parameters to which it may reach. Antecedent set contains parameter itself and other parameters which may reach to it. Depending on intersection of these sets, the parameters are partitioned in hierarchical levels.

(v) Construction of interpretive structural modeling
From the partitioned set of parameters and reachability matrix, structured model is derived, indicating parameters in each level and arrows indicating direction of relationship present. Such a graphic representation of model is called diagraph.

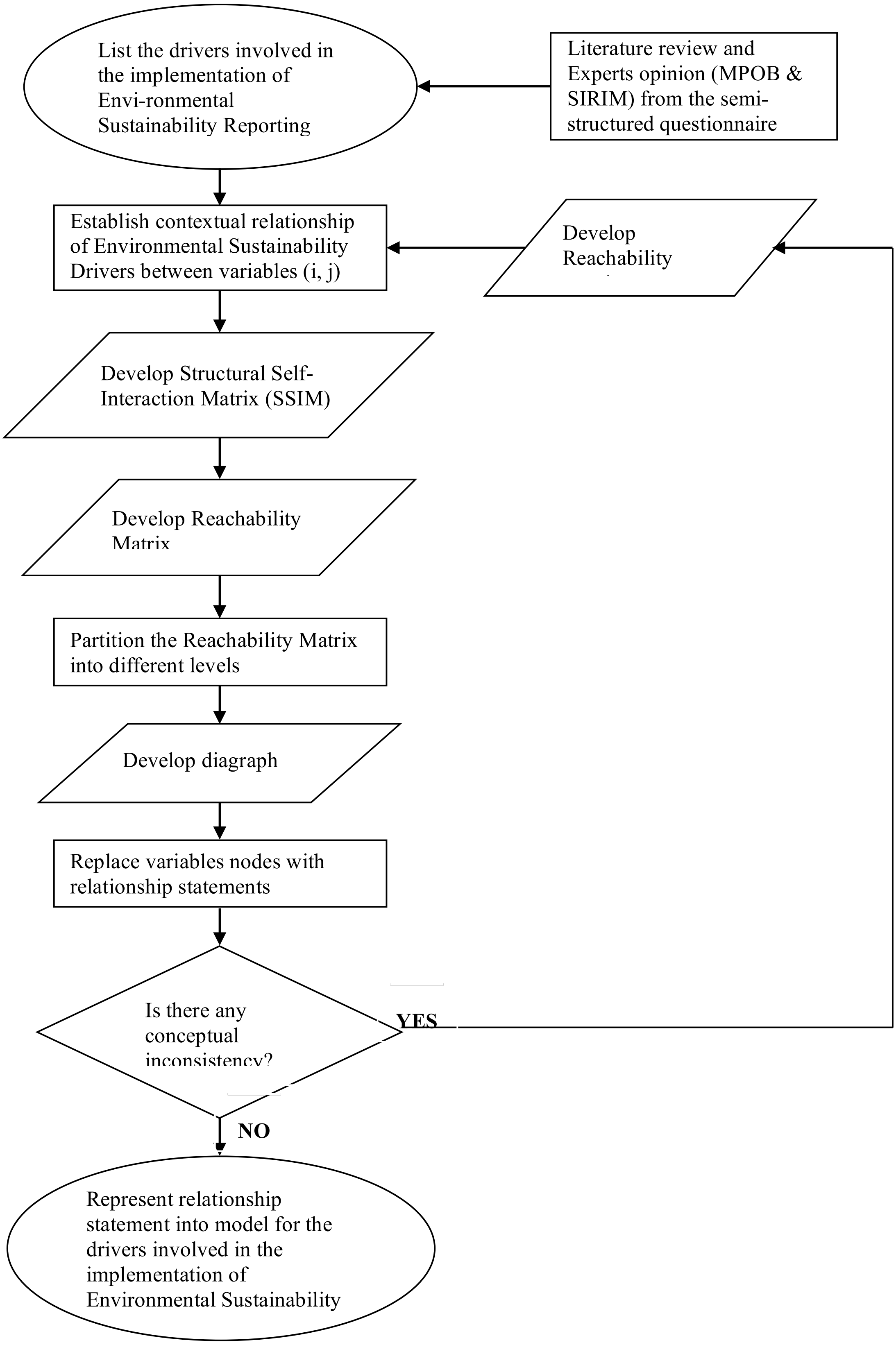

Figure 3. Flowchart of interpretive structural modeling methodology.

In this paper, the examples of contextual relationship between parameters in environmental sustainability were analysed using the interpretive structure modelling. The first step of using interpretive structural modelling was to analyse the contextual relationship of type "leads to".

That is one environmental sustainability (ES) parameter leads to another parameter. Based on this contextual relationship, a structural self-interaction matrix was developed. The various steps involved in interpretive structural modelling methodology are shown in the flowchart in Figure 3 (Kannan, Pokharel & Sasikumar 2009).

3. Results and discussion

3.1. Structural self-interaction matrix

The first step is to analyze the contextual relationship of type "leads to". That is one Environmental Sustainability leads to another. Based on this contextual relationship, a structural self-interaction matrix is developed. In this research, 3 experts, from the research based industries were consulted in identifying the nature of contextual relationship among the environmental sustainability drivers.

Water, soil and air quality (without pollution) determine agricultural sustainability (Acton & Gregorich 1995; Papendick & Parr 1992) and environmental quality (Pierzynski, Sims & Vance 1994) and have impacts on environmental pollution, degradation and depletion of natural and non-renewable resources (Power 1996). Applying renewable resources will minimise pollution and by using green labelling and life cycle assessment will help to provide qualitative and quantitative information regarding consumption of material. Energy use is a major source of emissions, thus achieving energy efficiency is important to control greenhouse gas emissions, assessing life cycle and managing the environment. Concerns about degradation of natural resources and climate change have triggered the need for preventive measures of environmental protection. Promotion of renewable resources and green labelling will be achieved by implementing life cycle assessment and environmental management systems. These will help to reduce the greenhouse effect. The development of an Environmental Management System (EMS) includes rational land use planning, water management, energy management (promotion of renewable energy sources, promotion of clean and energy efficient technologies), waste management (minimization, recovery, reuse, recycle, etc.) and life cycle assessment. Waste management is regarded to re-use, recycle, repair, life extension, incineration (with or without energy recovery), landfill and composting and is unrelated to climate change and GHG emissions. Water, soil and air quality are referred to unpolluted and emissions which can lead to erosion, climate change and ozone depletion. They are not related to energy efficiency and green labelling. Renewable resources are non-depletable resources which can be used in a cleaner and more efficient technologies manner and non-related to GHG emissions. Energy efficiency and climate change are not related to green labelling.

Following, four symbols are used to denote the direction of relationship between the Environmental Sustainability Drivers (i and j):

V: ES i will help to achieve ES j		
Environmental Sustainability of i	will help to achieve	Environmental Sustainability of j
Water, Soil and Air Quality		Climate Change
Renewable Resources		Green Labelling Life Cycle Assessment

Energy Efficiency		GHG Emissions Life Cycle Assessment Environmental Management
A: ES j will be achieved by ES i		
Environmental Sustainability of j	will be achieved	Environmental Sustainability of i
Renewable Resources		Climate Change
Climate Change		Life Cycle Assessment Environmental Management
Green Labelling		Environmental Management
X: ES i and j will help to achieve each other		
Environmental Sustainability of i	will help to achieve each other	Environmental Sustainability of j
Waste Management		Water, Soil and Air Quality Renewable Resources Energy Efficiency Green Labelling Life Cycle Assessment Environmental Management
Water, Soil and Air Quality		Renewable Resources GHG Emissions Life Cycle Assessment Environmental Management
Renewable Resources		Energy Efficiency Environmental Management
Energy Efficiency		Climate Change
Climate Change		GHG Emissions
GHG Emissions		Green Labelling Life Cycle Assessment Environmental Management
Green Labelling		Life Cycle Assessment
Life Cycle Assessment		Environmental Management
O: ES's i and j are unrelated		
Environmental Sustainability of i	unrelated to	Environmental Sustainability of j
Waste Management		Climate Change GHG Emissions
Water, Soil and Air Quality		Energy Efficiency Green Labelling
Renewable Resources		GHG Emissions
Energy Efficiency		Green Labelling
Climate Change		Green Labelling

Based on expert's responses, the structural self-interaction matrix is constructed as shown in Table 1.

3.2. Reachability matrix

The structural self-interaction matrix for environmental sustainability is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1s and 0s are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Then its transitivity is checked (which means if Environmental Sustainability of i leads to Environmental Sustainability of j and Environmental Sustainability of j leads to Environmental Sustainability of i, then Environmental Sustainability of i should lead to Environmental Sustainability of j) and the final reachability matrix as shown in Table 2 is obtained. In this table, the driving power and dependence of each Environmental Sustainability's are also shown. The driving power of a particular Environmental Sustainability is the total number of Environmental Sustainability (including itself) which it may help to achieve. The dependence is the total number of Environmental Sustainability which may help achieving it.

Table 1. Structural self-interaction matrix for Environmental Sustainability.

Environmental Sustainability	9	8	7	6	5	4	3	2	1
1.Environmental Management	**X**	**X**	**X**	**V**	**A**	**X**	**A**	**X**	-
2.Life Cycle Assessment	**X**	**X**	**V**	**V**	**A**	**X**	**X**	-	
3.Green Labeling	**X**	**O**	**V**	**O**	**O**	**X**	-		
4.GHG Emissions	**O**	**X**	**O**	**V**	**X**	-			
5.Climate Change	**O**	**V**	**A**	**X**	-				
6.Energy Efficiency	**X**	**O**	**X**	-					
7.Renewable Resources	**X**	**X**	-						
8.Water, Soil and Air Quality	**X**	-							
9.Waste Management	-								

Table 2. Final reachability matrix.

Environmental Sustainability Drivers	1	2	3	4	5	6	7	8	9	Driving Power
1.Environmental Management	1	1	0	1	0	1	1	1	1	7
2.Life Cycle Assessment	1	1	1	1	0	1	1	1	1	8
3.Green Labeling	1	1	1	1	0	0	1	0	1	6
4.GHG Emissions	1	1	1	1	1	1	0	1	0	7
5.Climate Change	1	1	0	1	1	1	0	1	0	6
6.Energy Efficiency	0	0	0	0	1	1	1	0	1	4

7.Renewable Resources	1	0	0	0	1	1	1	1	1	6
8.Water, Soil and Air Quality	1	1	0	1	0	0	1	1	1	6
9.Waste Management	1	1	1	0	0	1	1	1	1	7
Dependence Power	8	7	4	6	4	7	7	7	7	

3.3. Level partitions

From the final reachability matrix, the reachability set and antecedent set for each ES is found. The reachability set includes Environmental Sustainability itself and others which it may help to achieve, similarly the antecedent set consists of Environmental Sustainability itself and the other Environmental Sustainability's which help in achieving it. Then, the intersection of these sets is derived for all Environmental Sustainability's. The Environmental Sustainability for which the reachability and intersection sets are same is the top-level Environmental Sustainability in the interpretive structural modeling hierarchy.

Table 3. Iteration i.

Environmental Sustainability Drivers	Reachability Set	Antecedent Set	Intersection Set	Level
1.Environmental Management	1,2,4,6,7,8,9	1,2,3,4,5,7,8,9	1,2,4,7,8,9	**I**
2.Life Cycle Assessment	1,2,3,4,6,7,8,9	1,2,3,4,5,8,9	1,2,3,4,8,9	
3.Green Labeling	1,2,3,4,7,9	2,3,4,9	2,3,4,9	
4.GHG Emissions	1,2,3,4,5,6,8	1,2,3,4,5,8	2,3,4,5,8	
5.Climate Change	1,2,4,5,6,8	4,5,6,7	4,5,6	
6.Energy Efficiency	5,6,7,9	1,2,4,5,6,7,9	5,6,7,9	
7.Renewable Resources	5,6,7,8,9	1,2,3,6,7,8,9	6,7,8,9	
8.Water, Soil and Air Quality	1,2,4,7,8,9	1,2,4,5,7,8,9	1,2,4,7,8,9	**I**
9.Waste Management	1,2,3,6,7,8,9	1,2,3,6,7,8,9	1,2,3,6,7,8,9	

The top-level Environmental Sustainability in the hierarchy would not help achieve any other Environmental Sustainability above its own level. Once the top-level ES is identified, it is separated out from the other Environmental Sustainability's (Table 3). Then, the same process is repeated to find out the Environmental Sustainability's in the next level. This process is continued until the level of each Environmental Sustainability is found. Results for the iteration process are summarized in Table 4. The resulting levels help in building the digraph and the final model.

Table 4. Iteration ii-v.

Iteration	ES's	Reachability Set	Antecedent Set	Intersection Set	Level
ii	2	2,3,4,6,7,9	2,3,4,5,9	2,3,4,9	**II**
ii	3	2,3,4,7,9	2,3,4,9	2,3,4,9	**II**
iii	7	5,6,7,9	6,7,9	6,7,9	**III**
iii	9	6,7,9	6,7,9	6,7,9	**III**
iv	4	4,5,6	4,5	4,5	**IV**
iv	5	4,5,6	4,5,6	4,5	**IV**
v	6	6	6	6	**V**

3.4. Building the ISM model

From the final reachability matrix (Table 2), the structural model is generated. If there is a relationship between the Environmental Sustainability's i and j, this is shown by an arrow which points from i to j. This graph is called a directed graph, or digraph. After removing the transitivity's the digraph is finally converted into the interpretive structural modeling-based model (Figure 4).

Several interesting findings for the implementation of environmental sustainability arise from the application of interpretive structural modelling approach. The findings offered new considerations regarding the successful implementation of sustainability reporting. In this analysis, the dependence power and driver power of the variables are analyzed. On the basis of the above study, the drivers were classified into four sectors. The four sectors are autonomous, dependent, linkage, and driver/independent (refer to Figure 5). In the final reachability matrix, shown in Table 3, the driving power and dependence of each of the drivers are calculated. The drivers that have weak driver power and weak dependence will fall in Sector I and are called autonomous drivers. Drivers that have weak driver power, but strong dependence power will fall in Sector II and are called dependent drivers. Drivers that have both strong driver power and dependence power will fall in Sector III and are called linkage drivers. These drivers are unstable due to the fact that any action on these drivers will affect the others, and may also have a feedback effects on themselves. Drivers that have strong driver power but weak dependence power will fall in Sector IV and are called independent drivers (Kannan & Haq 2007).

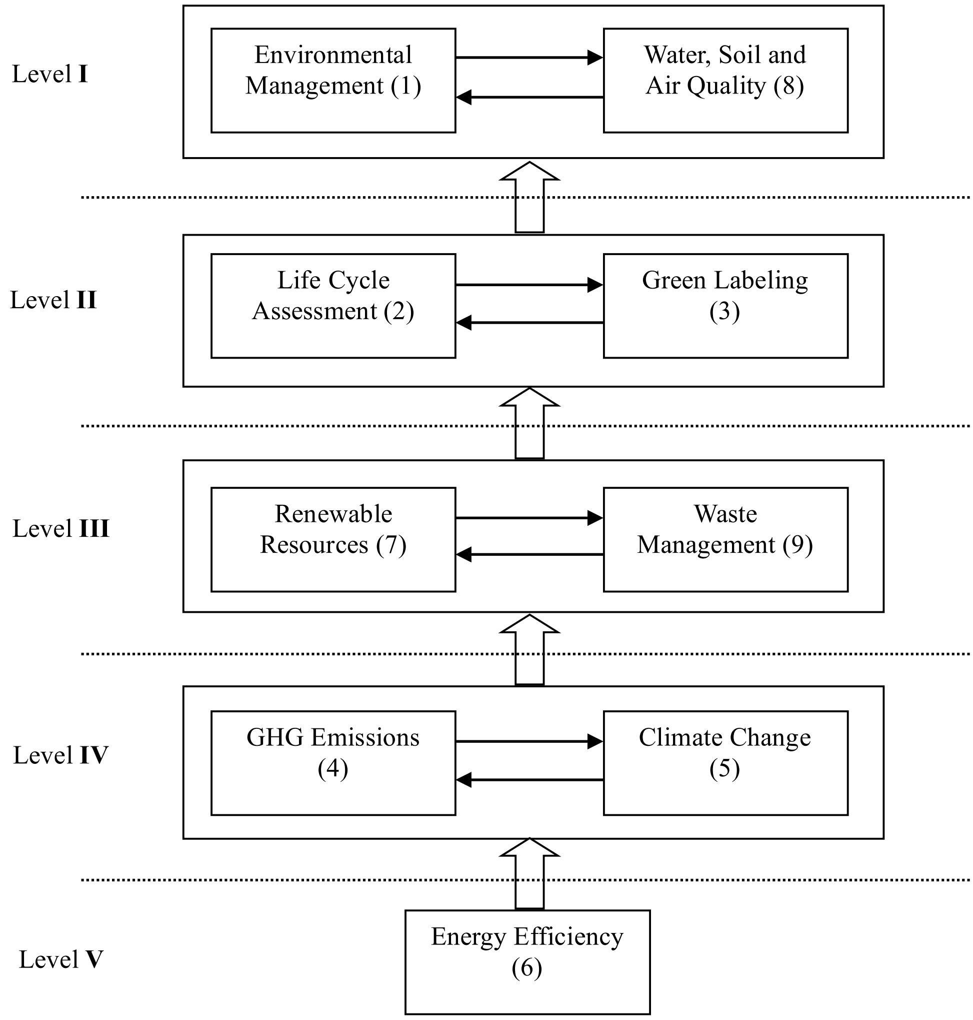

Figure 4. Structural model of Environmental Sustainability Drivers.

From the structural model of environmental sustainability generated, it showed that ISO14001 (Environmental Management Systems) and ISO14040 (Life Cycle Assessment) were at the top and second level. This model has concluded that the significance of these tools application as part of a useful guideline to aid decision making in sustainability reporting based on the analysed parameters and evaluation of environmental sustainability criteria. The drivers involved in the environmental sustainability reporting for Malaysian palm oil industry case study pose considerable challenges. Decision makers must be aware of the relative importance of the various drivers and the techniques for implementing them. Highlighting the 9 types of drivers, an interpretive structural modelling-based model was developed and the interactions between these drivers were analyzed. From Figure 4, it is evident that energy efficiency is the significant driver to reduce and eliminate product environmental impact, which is in tern critical to achieving the sustainability certification between suppliers in the supply chain network. Life cycle assessment, green labelling, renewable resources, waste management, GHG emissions and climate change are placed at an intermediate level of the interpretive structural modelling-based model. Environmental management and water, soil and air quality are at the top level of the interpretive structural modelling-based model hierarchy.

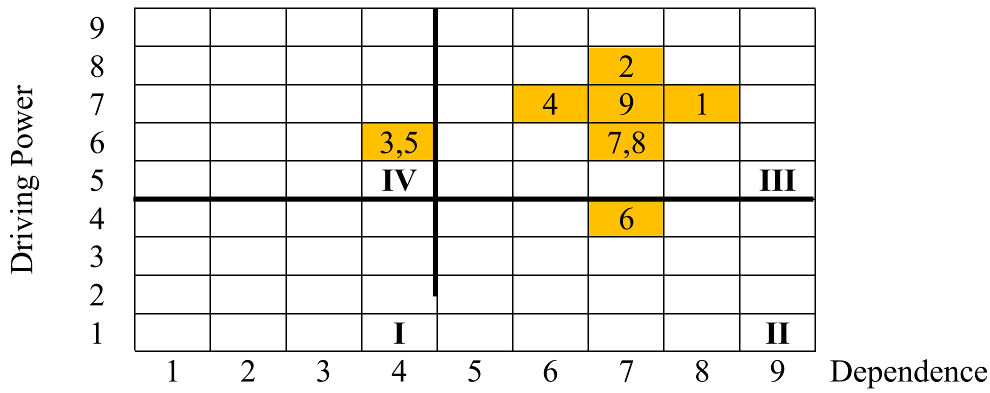

Figure 5. Driving power and dependence diagram.

Sector **I**: Autonomous Driver
Sector **II**: Dependent Driver
Sector **III**: Linkage Driver
Sector **IV**: Independent Driver

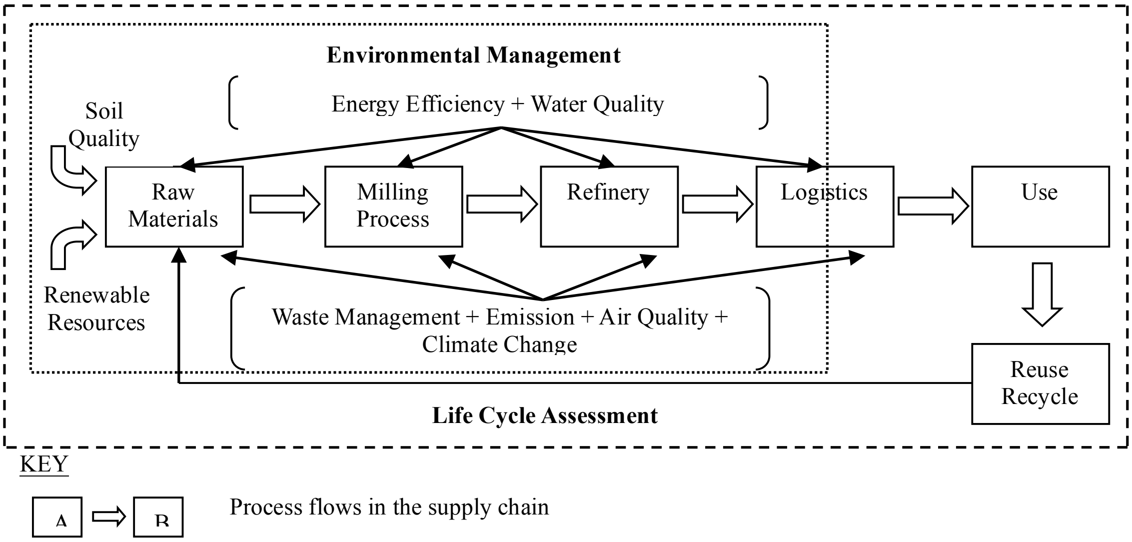

Figure 6. Environmental sustainability reporting drivers in the Malaysian palm oil industry.

3.4. Predicting the palm oil products life cycle to improve sustainability reporting

From the driving power and dependence diagram shown in Figure 5, it is evident that there is no driver that has weak dependence and weak driving power, so there are no drivers that map to Sector I. Next, the energy efficiency driver is found to have weak driving power and strong dependence power so it maps to Sector II. In this case, implementation of environmental management, life cycle analysis, GHG emissions, renewable resources, water, soil and air quality and waste management are found to have strong driving power and strong dependence power so they map to Sector III. These drivers are unstable due to the fact that any change occurring to them will affect other drivers and may be affected through a feedback mechanism (Qureshi, Kumar D & Kumar P 2008). Lastly, the green labelling and climate change drivers possess strong driving power and weak dependence power so they map to Sector IV. The above model is based on the interpretive structural modelling methodology, which has its own limitations. For example there will be subjective bias of the person who is judging the drivers, as the relations among the drivers always depends on that person's knowledge and familiarity with the industry.

Table 5. Examples of environmental sustainability drivers' indicators and units of life cycle stages of the Malaysian palm oil industry.

Environmental Sustainability Drivers	**Indicators**	**Units**
1) Environmental Management	Compliancy to the Environmental Management Standards	Number or %
2) Life Cycle Assessment	A specific entire product life cycle from the environmental point of view	Number or %
3) Green Labeling	Labels on products indicating carbon footprints, water and energy use, resource consumption and health impacts	Number or %
4) GHG Emissions	Emissions in total	CO_2 equivalent kg/yr or t/yr
5) Climate Change	Contribution to global warming	CO_2 equivalent
6) Energy Efficiency	Energy used in total	TJ/yr

7) Renewable Resources	Rate of renewable resources (relative to total world/regional reserves)	%
8) Water, Soil and Air Quality		
For water	Amount of water used	m^3/yr
For soil	Amount of soil used	ha/yr
For air	Amount of air pollutions	kg/yr or t/yr
9) Waste Management	Amount of solid waste (hazardous or non-hazardous)	kg/yr or t/yr

Issues of product sustainability are being undertaken in supply chain network by using simulation analysis and subsequently to ascertain a novel approach to outline a guideline of their product life cycle. It is intended that the standard of environmental sustainability reporting can utilize these drivers (shown in Figure 6) as part of a useful guideline to aid decision making. The novelty of this research is that it identifies the significance of environmental sustainability reporting based on the analyzed drivers and provides evaluation of environmental sustainability criteria's. This paper has provided a structural model of environmental sustainability and its associated method was developed by using the interpretive structural modelling model to determine the potential drivers in environmental sustainability reporting. The developed model can be used in the design life cycle of a product whether it is viable to be reused, remanufactured or recycled and subsequently to improve its sustainability. Indicators and units examples of the environmental sustainability indicators and units of life cycle stages related to the Malaysian palm oil industry were shown in Table 5.

4. Conclusion

In order to achieve sustainable products, an interpretive structural modelling approach was conducted to better understand the drivers related to environmental sustainability reporting in the supply network chain related to the Malaysian palm oil industry. This paper has identified nine (9) environmental sustainability drivers and the relationships between them. The findings from the environmental sustainability reporting drivers of this study can be furthered use to explore the potential impacts of supply chain network design on sustainability using the Malaysian palm oil industry as a reference.

The decision makers related to the Malaysian palm oil industry will be directly benefited from the outcome of this research, as this would help them in prioritizing decision-making efforts on various issues. The interpretive structural modelling is a useful tool for decision makers to differentiate between independent and dependent drivers and their mutual relationships. This would help them to focus on the identified key parameters that are important for effective implementation towards the definition of sustainability in the Malaysian palm oil industry. The strongest driver in the decision-making process of this industry is energy efficiency. By increasing energy efficiency will help to reduce the impact of energy consumption on climate change. This is perhaps the reason why issue relating to energy efficiency is in the level of the strongest driver. This issue has triggered the next level of issues, which includes greenhouse gas emissions and climate change. As climate change is primarily affected by the greenhouse gas emissions, replacing non-renewable energy with alternative renewable and low impact energy sources can help to increase energy efficiency. The next level of issues as shown in the interpretive structural modelling-based model in Figure 4 covers the issues related to renewable resources and waste management. This level of issues is primarily at the cradle-to-grave life cycle, where efficient use of renewable resources and successful implementation of waste management will ensure long term sustainability achievement. In the next level of issues, life cycle assessment and green labelling are applicable to provide an assessment of the potential environmental impacts of all inputs and outputs throughout the production chain and to produce environmental friendly products. The final issues are the environmental management and water, soil and air quality which are important to access environmental impacts and to prevent contamination.

The importance of having clear information requirements based on the different impacts in the supply network tiers can be used to capture data related triple bottom line performance indicators in the design of sustainable industrial systems (Choong & Alison 2013). As an example, green labelling for carbon footprint is part of the control measures taken to reduce environmental impact of products and services throughout the life cycle of the Malaysian palm oil industry supply network. As for further research, simulation analysis can be carried out to determine the influence effect of these drivers had on the performance of the network. From the performance analysis, focus can be better made on the sensitivity of triple bottom line to factors of uncertainties of the supply chain network in order to understand the potential risks of sustainability in palm oil supply chain network and could be diagnosed for better sustainability development indicators.

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Ecomimesis: A Model for Sustainable Design

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Abstract

Background. In the last fifty years there have been scientific empirical evidence that climate change and environmental degradation are increasing and over 500 international agreements with goals to stem the deterioration of the land, sea, and air. Despite all the evidence and treaties, climate change is getting worse with ever increasing air and water pollution, soil and ocean degradation, and ecosystem decline. Method and results. Based on both extensive research and monitoring of the harmful contributors to the environment and specific components of the ecosystem and current design remedies to ameliorate that damage, this paper provides an analysis of the negative anthropogenic impact on various parts of the ecosystem and proposes ecomimetic design solutions to mitigate and repair environmental degradation. This article focuses on these major components of the ecosystem: biodiversity, spatial efficiency, homeostasis and its subsets of cybernetics, succession, and continuity. These components are described with emphasis on the damage inflicted by anthropogenic actions. Each section will include proposed ecomimetic solutions to repair and mitigate the damage. Conclusion. While there is no single solution to the environmental challenge, ecomimesis represents a comprehensive and achievable approach toward slowing and correcting environmental decline. It is different from other design models because it considers all the major components of the ecosystem and designs the manmade ecosystem to minimize adverse effects and help stabilize the environment. Using nature as its template, ecomimesis conserves, repairs, and improves existing ecosystems. Ecomimesis is a new and broad approach to ecodesign.

Keywords: Climate change, Ecomimesis, Ecosystems, Sustainable design

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1. Introduction

For the last fifty years scientific research from private and public groups has shown that climate change and environmental degradation have been the result of an increased world population, economic development and industrialization, and the changes in social and cultural norms. Although these three fundamental components were highlighted in Gro Harlem Bruntland's report in 1987 for the United Nations, Our Common Future, which warned of the urgency to protect the world's environment and natural resources, the pace of economic growth and depletion of natural resources continues to gain momentum without regard to the health of the environment and the world population.

Although the effects of greenhouse gases have dominated research and public policy in recent years because of the global warming they cause, there are many other harmful contributors to the environment. These other factors and their negative impact on various parts of the ecosystem will be the focus of this article.

This article will discuss the following ecosystem components: biodiversity, spatial efficiency, and homeostasis which includes subsets of succession, cybernetics, and biogeochemical cycles. To retain stability within an ecosystem, each component must contribute its part. If any component is damaged or eliminated, the entire ecosystem goes into flux until it regains equilibrium by adjusting to its new composition.

Following a detailed description of the damage inflicted by anthropogenic actions on each component, there will be proposed ecomimetic solutions to repair and mitigate the environmental damage.

2. Ecomimesis

Ecomimesis is the term used to describe the design of manmade ecosystems that imitate ecosystems in nature. Ecomimesis emulates the properties, structure, functions and processes of natural ecosystems in designing and constructing the manmade ecosystem. By using nature as its template, ecomimesis is ecologically driven to conserve, repair and improve existing ecosystems, to re-establish ecosystem stability, and to preserve regional biodiversity and habitats through continuity of functions and connectivity.

What distinguishes ecomimesis from other sustainable design programs is its scope. Other sustainable design programs usually focus on only a few aspects of the built structure or environment, such as energy conservation, carbon footprint, or flood control. Ecomimesis analyzes the whole ecosystem, the impact of human activities on that particular ecosystem, and creates designs which minimize the damage to the natural ecosystem. The inclusion of the entire ecosystem and the impact of human activities on the ecosystem result in anthropogenic structures and resource use that minimize damage and intrusion to the existing ecosystem.

In creating a built environment within nature’s ecosystem, ecomimesis attempts to mimic the ecological cycles, networks, relationships between components, and diversity of local plants, animals, and environmental conditions so that built structures, community, or society impose a minimal disruption of the natural balance of the system. All aspects of the built environment – site use, architectural and landscape designs and master planning, product designs, material selection and use, types of energy systems, waste generation and management, forestry, and agriculture, for example - must be analyzed and incorporated into ecomimetic designs so that the resulting designs are systematically integrated physically and spatially with the existing ecosystem. The creation of new eco-sensitive manmade structures can also assist in reclamation efforts to restore cities and environments to a more congenial state with the natural ecosystem.

Ecomimetic designs of the built environment will become a mirror image of the designs of natural, self sustaining, and self correcting ecosystems, if the principles that govern the balance and interdependence of a natural ecosystem are used as a model for manmade environments. By using ecomimetic design for architectural and other manmade ecosystems to duplicate the properties, structure, functions, and processes of ecosystems in nature, a benign integration between the two ecosystems can be achieved.

Other benefits of ecomimesis are the reduction and restoration of damage to the environment and a positive impact on ecosystems. Some of the benefits would include strengthening biodiversity, purifying water and bodies of water, reducing polluting emissions, reducing waste, stabilizing biogeochemical cycles and the nutrients in the soil, using land more efficiently and carefully, and limiting manmade ecological footprints. (Yeang, Ecodesign Manual, 45-58).

3. Ecosystem

An ecosystem is essentially a set or collection of organisms that lives within a certain space determined by a specific environment. Each ecosystem community is a complex of species, their physical environment, and all their interrelationships in a particular unit of space. The species interact with each other and with the energy and abiotic components (air, water, soil) of that physical environment. Ecosystems vary in size and location, such as aquatic, coastal, coral reefs and ponds, deserts, forests, rain forests, grassland, tundra and others. The ecosystem types are determined and influenced by climate.

The primary elements that constitute the fundamental structures and organization of ecosystems include biodiversity, spatial efficiency, ecological cybernetics, homeostasis, succession, energy, and biogeochemical cycles. Each element is necessary for the continuity and balance of an ecosystem. If any part is disrupted from its natural ability to adapt and adjust, other parts will also be affected.

Every ecosystem is subject to and controlled by external and internal factors. External factors influence the structure of the ecosystem through climate and its temperature and rainfall, geological material that determines mineral nutrients in the soil, and topography that establishes microclimates and water sources and retention. Internal factors include processes, disturbances, and changes that affect its composition and stability. Among them are primary production of organic material through photosynthesis, energy flow, decomposition and nutrient cycling.

An ecosystem's stability depends on its ability to maintain and sustain its existing elements. Those elements, the internal and external factors are mentioned above. In addition, ecosystem equilibrium is dependent on its ability to survive natural disasters like floods and hurricanes, land erosion, desertification caused by heat and drought, and degradation of the soil.

Researchers estimate that approximately 40-50% of the land surface of Earth has been degraded by anthropogenic activities, 66% of marine fisheries have been overfished, carbon dioxide in the atmosphere has increased more than 30% since the beginning of industrialization, and almost 25% of the Earth's bird population are now extinct. (Vitousek et al., 277: 494-499)

4.1. Ecosystem: Biodiversity

4.1.1. Background

In any given area biodiversity is determined by number of species that can adapt and survive in a specific ecosystem. Ecologists estimate that there are approximately 1.7 million species that have been described and probably another 10-30 million species that exist but have not been described.

Most of the world's 1.7 million species are concentrated near the equator, particularly in tropical rain forests and coral reefs. Only 10-15% of the world's species live in North America and Europe. The Malaysian Peninsula, for example, has 8,000 species of flowering plants while Britain, with an area twice that, has only 1,400 species. South America, on the other hand, has over 200,000 species of plants. (Cunningham, 108; United Nations Environment Programme. Convention on Biological Diversity. June 1992.)

The general view among biologists and ecologists is that ecosystems with more kinds of different species are stronger than those with fewer species because more species strengthen an ecosystem's resiliency and ability to adapt to changes. (Moffatt, 1996.) In some ecosystems the diversity helps create a stronger homoeostasis by providing greater numbers of species that can assist in processing food through their complex webs. In other ecosystems diversity can result in wide population swings for individual species, and in some cases, these species become extinct. (Bush,169; Moffat,1996; Cunningham, 108.)

The preservation of biodiversity of a specific area is controlled by two major factors: 1) the abiotic components: minerals, climate, soil, water, and sun. and 2) the biotic components: the types of organisms and their interactions, the balance of producers, consumers, decomposers, and integrators, the food chain, factors that affect population growth, and community properties. Changes to any of these factors can affect the ecobalance and ultimately the existing biodiversity of a given ecosystem.

4.1.2. Findings: Human impact on ecosystems and biodiversity

Human actions have caused a number of dramatic changes to a variety of ecosystems. Humans use and modify natural ecosystems through agriculture, forestry, recreation, urbanization, and industrialization, and in the process of these activities, both the balance of ecosystems and their ability to support indigenous species are adversely affected.

Current biodiversity losses are primarily caused by disruptions of ecosystem balances. If one element breaks down or is disrupted, the balance of the entire ecosystem is threatened. Most of the disruptions that have resulted in the loss of biodiversity are caused by human activity: habitat alteration or destruction, deforestation, human overpopulation, introduction of new species and genetically modified organisms, pollution, and climate change. (Eni Scuola.net/.) World Wildlife Global has estimated that the rapid loss of species is somewhere between 1,000 and 10,000 times higher than it would have been from natural extinction. (McLamb, 2013.)

In 2014 World Wildlife Fund issued its biennial Living Planet Report, which measures trends in three areas: populations of more than 10,000 vertebrate species, human ecological footprint, and biocapacity. The data compiled by WWF indicates that between 1970 and 2010 populations of mammals, birds, reptiles, amphibians, and fish around the world decreased by 52%. Specifically, in the forty year span, 39% of terrestrial wildlife, 30% of marine wildlife, and 76% of freshwater wildlife are gone. While high income countries showed a 10% increase in biodiversity, middle income countries showed an 18% decline, and low income countries showed the biggest decline in biodiversity, 83%. (Roberts et al, 2014.)

Human impact on biodiversity can be summed up with the acronym, HIPPO: 1) Habitat fragmentation and destruction 2) Invasion of non-native species 3) Pollution 4) Human population and 5) Over harvesting. We can also add climate change and the domino effect of all these factors. (Miller, 132)

Habitat fragmentation and destruction Fragmentation and degradation of natural habitats and the environment are directly related to resource consumption and land use changes. For example, tropical forests are being cut at a rate of 0.6 to 2% per year, and it has been estimated by the United Nations Environment Programme that half of remaining forests will be lost or degraded in 25 to 83 yrs. The number of extinctions caused by human domination of ecosystems has been steadily increasing since the start of the Industrial Revolution. Current research indicates that about 50% to 84% of the Earth's surface (excluding Antarctica and Greenland) has been lost by filling in wetlands, and converting grassland and forests to crop fields and urban areas. (UN Global Biodiversity Outlook 4 2011-2020, 11-13)

In U.S. at least 95% of virgin forests in the lower 48 states have been logged for lumber and converted to agriculture, housing, industry. 98% of tall grass prairie in the Midwest and Great Plains have disappeared, and 99% of California's native grassland and 85% of its original redwood forests are gone. More than half of U. S. wetlands have been destroyed. (Cal State University, 2009.)

Invasion of non-native species and decline of natural key predators. The spread of non-native species threatens many local species with extinction and pushes the world's biota toward a more homogeneous and widely distributed sub-set of survivors. Climate change threatens to force species and ecosystems to migrate toward higher latitudes, with no guarantee of suitable habitat or access routes.

In 2016 Nature World News reported the results of a study that found that fish are migrating toward the poles and away from the equator because of warming temperatures. The study also found that plants and trees are also shifting out of temperate zones as temperatures rise. The research team concluded that the plant and fish migration will have adverse effects on poor nations in the world. (Catherine Arnold, 2016.)

Researchers indicate that fresh water ecosystems are currently the most threatened ecosystems. With the destruction of natural barriers, invasive species take over the ecosystem, destroying the native species. The rampant spread of invasive species has been attributed to human activities. (http://www.conserve-energy-future.com/what-is-biodiversity)

Pollution Human impact on abiotic components has included toxicity, global warming, increased ozone, increased carbon dioxide, increased greenhouse gases, fragmentation and degradation of biogeochemical, water and hydrologic cycles, air and their impacts on climate change and environmental pollution, and interference with normal cycling and flows of energy in ecosystems.

Population Humans are the only species whose population keeps growing beyond an ecosystem's ability to support it. With all other species, overpopulation results in dying back until the environment can accommodate it. Human beings have overcome this natural limitation by changing their physical environment. As a consequence, the ever increasing human population has resulted in greater and greater demands for food, shelter, and settlements, and products that steadily consume more than their share of resources. As a result, the natural balance of the environment has been damaged. Urban sprawl has resulted in increased paved surfaces and increased heat island effects. At the same time, there are fewer open fields, forests, marshlands, and other natural habitats. Similarly, commercial farming and forestry have created monocultures, adversely affecting the soil, ground water, rivers, and other bodies of water and extant species through the use of chemical fertilizer and pesticides.

Overharvesting of nonrenewable resources In a closed ecosystem there is no waste. Everything is used by some member of an ecosystem, and there is a circular pattern of using resources. Humans, on the other hand, practice a linear pattern of resource use: extract a resource, convert it for use, consume it, and throw it away after it is no longer wanted or useful. This practice has resulted in an accumulation of waste and depletion of nonrenewable resources. Many manmade products, that are discarded when their usefulness is completed but whose residual material do not decompose quickly or easily, are another source of waste. Ecomimesis design must adopt nature's way of using, reusing, and reintegrating materials.

4.1.3. Proposed ecomimetic designs to maintain ecosystem diversity

Ecomimesis seeks biointegration of the abiotic (inorganic) and biotic (organic) components, composition, and processes of the built environment with the natural environment to form a mutually beneficial ecosystem. Ecomimesis can help maintain ecosystem diversity through the following designs and actions:

1. Design to minimize fragmentation of ecosystems. Enhancing biodiversity of the designed system can be achieved through conservation of existing continuities and linkages of ecosystems, through the creation of new ecological corridors, eco-bridges, eco-undercrofts, land bridges, hedgerows, enhanced horizontal integration, and interconnectivity over terrain.

2. Design to minimize the distance between habitat patches and maintain the size of habitat patches. Design processes are affected by the character of the landscape, its size, shape, and patterns. Species composition and abundance will suffer as the size of habitat patches decreases. The amount of connectivity needed between patches varies from species to species and depends on the abundance of the focal species, its spatial arrangement and movement capabilities. (Yeang, Ecodesign Manual,41.)

3. Practice ecomaster planning. Both the site and its context should be based on maintaining the functions and connectivity within an ecosystem and repairing or restoring damaged ecosystems rather than on a fixed perception of the environment determined at the time of site analysis. Ecomaster planning differs from conventional master planning because it stresses a seamless and benign biointegration of the human ecosystem and the natural one. (Yeang, Ecomasterplanning, 16-18.)

4. Design a green infrastructure which is a network of interconnected natural areas and open spaces within the site which are linked to those outside it. This can heal landscapes, repair ruptures, reconnect parts, and can create an ecoinfrastructure.

5.Designate use of renewable resources. Use renewable sources only at the rate at which they can renew themselves, and do not use non-renewables faster than renewable substitutes can be developed, such as making plastics from plants and fuel from corn. In a stable ecosystem, prey species are never completely eliminated, and food plants are allowed to grow back.

6. Balance abiotic and biotic components in design systems to preserve biodiversity

a. Integrate a designed system's inorganic mass with biomass and design for rehabilitation of degraded ecosystems.

b. Buildings should include complements of roof gardens, vegetation inside and outside that interface with a built system's inorganic constituents to form a whole. (Todd and Todd,110.)

c. Balance interdependent living and non-living components so that there is a continuum interacting as a whole. Human made systems need to mimic the integrated balance of abiotic parts (built components which are mainly inorganic) in ecosystems with biotic constituents.

7. Enact public laws and regulations, and international treaties to protect biodiversity.

4.2. Ecosystem: Spatial efficiency

4.2.1. Background

Natural ecosystems combine compact spatial efficiency with high structural diversity among species of plants, animals, and abiotic factors in order to maintain a healthy functioning ecosystem. The essential natural conditions are climate and resources. Just as closed loop ecosystems have no waste because at least one species uses waste products produced by other species, they also do not take up more space than they need to maintain their balance.

4.2.2. Findings: Anthropogenic impact on spatial efficiency

Before the Industrial Revolution, humans lived mainly in rural areas where they supported themselves through natural resources- farming, hunting, mining, herding, fishing. Although there were many large cities in the world before the Industrial Revolution, urban areas developed and grew very quickly as the base of the economy changed from agricultural to industrial. More people moved to urban areas as societies and urban culture grew, labor became more specialized, and cities became more complex in their functions and governance Today there are great concentrations of human beings occupying every part of the globe that is habitable.

l. A major anthropogenic impact on spatial efficiency has been urban sprawl. This has resulted in increased population density, paved surfaces, and heat island effects. Urban sprawl in the developed world has created unlimited outward extension, low density development, and leapfrog development that changes land use from farmland and natural areas and forests to commercial and residential development and extensive manmade infrastructure, widespread strip malls and big box shopping centers, decaying city centers, congestion, heat island effect, excess use of non-renewable energy sources, water run-off, and atmospheric warming (Cunningham, 345.)

2. Governmental bodies have added to the urban ecology by creating policies that have often favored and encouraged urban over rural areas as drivers of economic development (Cunningham, 339-342.)

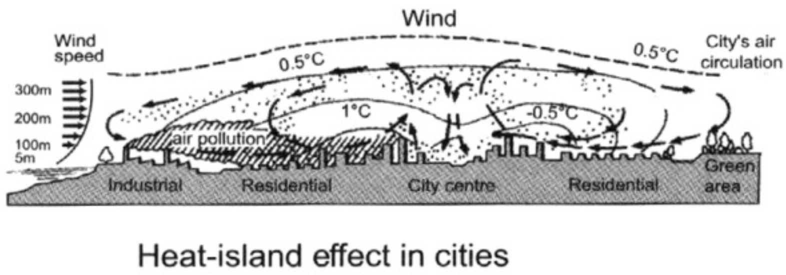


Figure 1. Heat island effect in cities (Yeang, and Woo, 117-118.)

4.2.3. Proposed ecomimetic designs that can emulate ecosystem spatial efficiency

1. Design and build compact structures and communities to maintain species diversity, ecological interactions among species (functional diversity) and to occupy space as efficiently as the plants and animals in the specific ecosystem.

2. Establish and further develop urban policies in the developed world that redesign cities so that they are spatially more efficient. (Cunningham, 347.)

3. Designer should research ecological history of site and establish an ecological baseline for planning design to protect and restore disturbed or degraded ecosystems

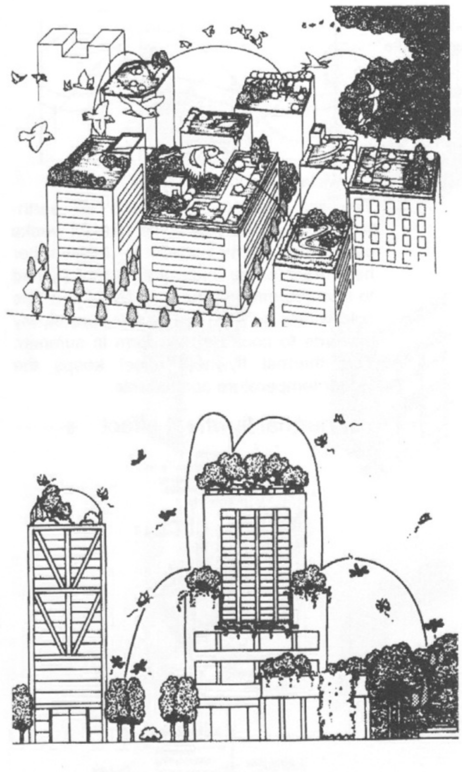


Figure 2. Roof gardens and sky courts that create new urban habitats (Yeang and Woo, 215.)

4. Design to reduce heat island effect of the built environment on the ecology of the locality. Reducing and improving urban micro-climate impacts (Yeang, *Ecodesign Manual,* 161.) Roof gardens and sky courts create new urban habitats.

5. Plan and construct compact use of space in building and development, synthesis of nature and neighborhoods, compact development of multifunctions to decrease the time spent to conduct business and living. (Todd and Todd, 115-118.)

6. Design to achieve integration with the environment, such as vertical integration: designing for multilateral integration of the designed system with ecosystems.

7. Design for temporal integration: use of non-renewable and renewable resources at rates less than the natural rate at which they regenerate. Designer needs to know how an ecosystem is structured: interdependence, change, cycling of ecosystems, soil, and composition in order to minimize damage, or even enhance, ecological connectivity that can be beneficial. Can use indicator species to measure environmental conditions and changes within built ecosystem. (Noss, (2005), 355-364.)

8. Establish urban planning and public policy based on l) limited city size or cities organized in modules; 2) greenbelts in and around cities to promote more efficient land use; 3) determine in advance where developments will take place within ecological systems; 4) locate shopping and services within walking distances of homes; 5) encourage walking; 6) promote more diverse and flexible housing as an alternative to conventional detached houses; 7) encourage city self-sustainability with locally grown food, waste and water recycling, 8) encourage cluster

housing which preserves at least half of a site as natural areas; 9) encourage "smart growth" that makes use of in-fill development and mixed use of land. (Cunningham, 347)

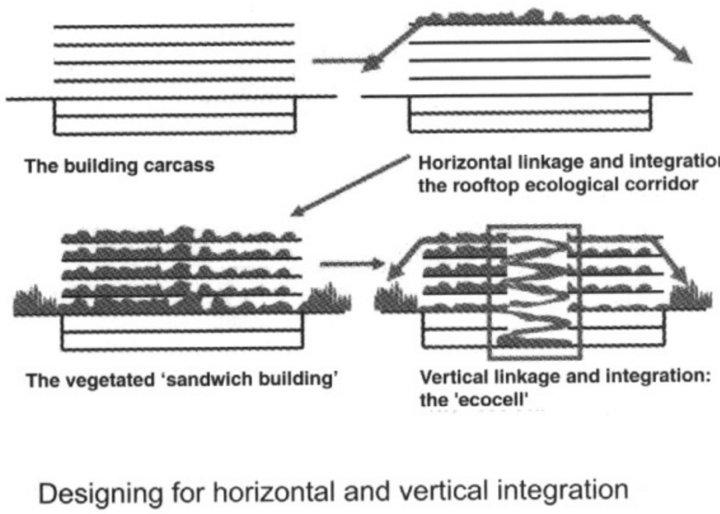


Figure 3. Horizontal and vertical integration (Yeang and Woo, 252.)

4.3. Ecosystem: Homeostasis

4.3.1. Background

Although it has not received as much public discussion as energy and biodiversity during the present attention to climate change, homeostasis, together with its subsets of cybernetics, succession, and continuity, is a component that accurately reflects the increasing vulnerability of ecosystems to maintain a natural balance.

Ecosystem homeostasis is the equilibrium state that results from environmental elements that must remain relatively stable. Among those are the biogeochemical cycles (carbon, oxygen, nitrogen, sulfur, and hydrology), soil, reabsorption, and reuse of materials and their effect on the composition of the ecosystem. These cycles are pathways through which chemical elements move through the biotic and abiotic compartments of Earth. The movement and storage of these chemicals allow living organisms to use them. Additions of new or foreign elements to an existing ecosystem change ecosystem dynamics. (Biology Dept., University of Illinois (2009); Biology Dept., University of Hamburg, (2003).) These changes affect the number of species, interactions among the species, and population size and can alter an ecosystem's ability to support the original interdependence among all the members of an ecosystem. In other words, the symbiotic balance of interconnection and interdependence among ecosystem components becomes disordered and unbalanced. When that happens, ecosystem succession results in a change in species composition and community structure because of the changes in the physical environment. (Drudy et al., (1973), 331-368.)

Disruption or degradation to the ecosystem throws the ecosystem out of balance. The disruption of ecosystems can be caused by natural disturbances such as fire, floods, and droughts among others.

Other factors that interrupt ecosystem homeostasis are anthropogenic activities that disrupt biogeochemical cycles, contribute to eutrophication of bodies of water, increase global warming, and deplete natural resources.

Changes in biotic and abiotic conditions lead to a cascade of effects which ecosystem components process and exchange through new information (cybernetics). The time it takes for a system's return to homeostatic balance depends entirely on the length and severity of the interruptions of the ecosystem. (Odum,(1969); Smith, 613, 619, 627.)

Sustained in large part by both internal and external factors that help to maintain populations within the carrying capacity of the environment, homeostatic equilibrium is established through the exchange of new information and interlocking feedback loops which can reduce entropy of ecosystem components. (Odum, (1969); Patten and Odum, (1981), 886-895.) For example, the biotic information network on the semiannual great migrations in Africa depends on grazing, population density, attack-avoidance, prey abundance, natural selection, overcrowding. Nutrient cycling can provide information (feedback) about overshoots and destructive oscillations. These conditions regulate the health and stability of an ecosystem community and determine its stability. (Volkov et al., 2006.)

Ecosystems have the ability to resist limited changes resulting from human activities The ability of ecosystems to recover from small changes minimizes and sometimes negates the impacts of human actions. In many instances, though, human activities can overwhelm the recuperative capacity of natural systems

4.3.2. Findings: Human impact on ecosystem homeostasis

An ecosystem's homeostasis is altered by anthropogenic activities that create disturbances, fragmentation, damage to the atmosphere, disruption of cycles and abiotic and biotic components.

The depletion or alteration of natural resources or polluting the soil and air ecosystems may change the structure of the species by eliminating certain species from that particular ecosystem and by changing the composition of biodiversity in it.

Pollution is created by the burning of fossil fuels, using toxic substances that can be either airborne or discharged into the soil, and discharging wastes into water bodies.

Biogeochemical cycles have been altered through the extensive use of pesticides and chemical fertilizers. The Green Revolution, which was designed to increase crop production in underdeveloped countries, unwittingly contributed to the negative effects of monoculture. In addition to new crop hybrids suited for various climates, heavy use of chemical fertilizers, herbicides, insecticides in both developed and underdeveloped countries has disrupted the soil’s biogeochemical cycles and edaphic factors. Among the most serious changes have been: 1**)** increased susceptibility to diseases; 2) low tolerance to stresses of drought or temperature; 3) reduced resistance to insects; 4) famines resulting from crop failures; 5) decreased soil fertility and increased soil erosion; 6) increased habitat for pest species and reduced habitat for beneficial species. The same monoculture that disturbs homeostasis also has a negative impact on an ecosystem that leads to succession. (Gillis, 2009; North Carolina General Assembly.)

A 2016 study found that climate change is making it more difficult to grow staple crops in sub-Saharan Africa, with maize, beans, and bananas most at risk. Scientists with the CGIAR Research Program on Climate Change, Agriculture and Food Security indicated that 40% of the maize growing areas will need to be transformed with either new types of crops or abandonment of crop farming. The heat and drought conditions in this region of Africa make it necessary to replace the threatened crops with more heat tolerant crops within the next ten years. Adaptation to climate change has become urgent in high risk countries like Guinea, Zambia, Senegal, Burkina Faso, Niger, Ghana, Namibia, Botswana, Zimbabwe, and Tanzania. The current situation affects not only the food supplies for these countries but also their economic markets and social changes. (Rowling, 2016.)

In addition to agricultural runoff, sewage, paper and textile mills and food processing have stimulated oxygen consumption in water by decomposers, like aerobic bacteria and algae. As biochemical oxygen demand (BOD) in bodies of water increases through the oxygen consumed in the decomposition process, other aquatic organisms are robbed of the oxygen they need to live. The resulting eutrophication increases algal blooms and produces reduced water clarity, periods of hypoxia, loss of seagrass beds and coral reefs, and ecological changes in food webs.

By burning coal, oil, and natural gas, humans are adding carbon dioxide to the atmosphere much faster than the atmosphere can absorb it. Burning forests to create agricultural land also converts organic carbon to carbon dioxide gas. While oceans and land plants absorb part of the carbon dioxide, the rest is added to the atmosphere.

The sulfur, nitrogen, phosphorous, and oxygen, hydrologic, and carbon cycles have all added elements to croplands as fertilizers that have resulted in the elimination of indigenous vegetation, destruction of wetlands, eutrophication, soil erosion, and alteration of water quality. (Carnegie Mellon; Environmental Literary Council; Houghton; International Fertilizer Industry Association; H T Odum.)

Overuse or depletion of natural resources like overgrazing and pasture degradation, overfishing and replacement of commercially valuable fish by trash fish, and forest depletion through overharvesting or through fires have contributed to instability to ecosystem homeostasis.

Many human designed methods to integrate manmade ecosystems with natural processes of succession have been harmful to natural ecosystems. In dealing with rural and urban ecosystems, for example, human designers have ignored the natural process of ecological succession, preferring their own intensive inputs- built structures and infrastructures, intense use of artificial fertilizer- to maintain farmlands and cities and to develop urban sprawl haphazardly. These practices, in essence, are examples of human environmental succession in industrialized countries.

Conversely, in economically underdeveloped countries with long standing traditional societies, there remain many centuries' old practices that take advantage of ecological succession in ways that allow them to use fewer inputs.

4.3.3. Proposed ecomimetic designs to maintain or restabilize homeostasis

In order to maintain and ensure that the ecosystem factors needed for homeostasis are healthy and balanced, designs for the manmade ecosystem must include space efficiency and continuity, well functioning cybernetics, connectivity, and biogeochemical balances in soil and water. The following design recommendations are extensive because of the breadth and depth of elements needed to maintain and repair the balance of homeostasis.

1. Designs that maintain the balance of abiotic and biotic components in an ecosystem buildings through incorporated greenwall systems are good examples.

2. Ensure that energy source is renewable and materials can be reused when designing the built environment.

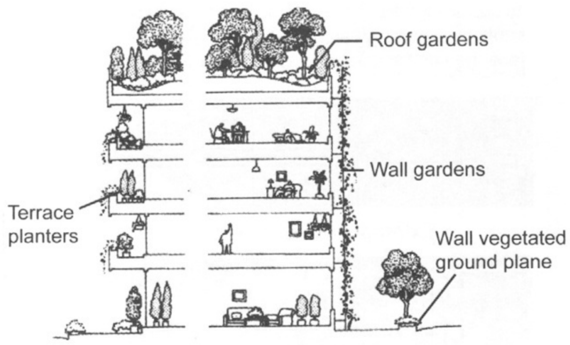
3. Design for efficient use of materials by l) designing to minimize amount of material used, resource depletion, and waste; 2) designing for adaptive use of buildings; 3) designing for disassembly–recycle, reintegrate, reuse, conserve non-renewable materials, and use renewable materials; 4) Using materials with a low ecological impact. This includes low toxic materials, non-chemical materials, natural biodegradable alternatives, such as plastics from corn.

4. Design roads and other built structures to minimize disruption of soil and biogeochemical cycles. Pollution absorbing concrete and porous paving for parking lots are examples.

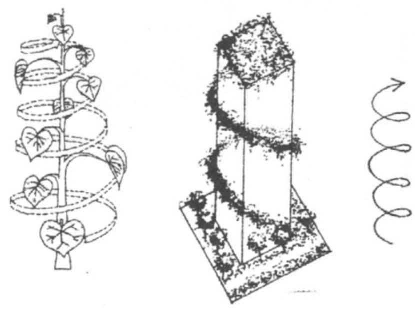
5. Assess the overall design (product, structure, infrastructure) for the level of environmental integration over its life cycle.

6. Since ecosystems use energy efficiently, manmade ecosystem designs should also include efficient operations of a building's environmental system through their robotic and automated building systems based on current technology.

7. Utilize deep plan, double envelope, double layered façade, ecocell, green roof, light pipes, and light shelf designs for new structures.



Vertical planting design



Continuous vertical landscaping

Figure 4. Illustration of green wall systems. (Yeang and Woo, 39.)

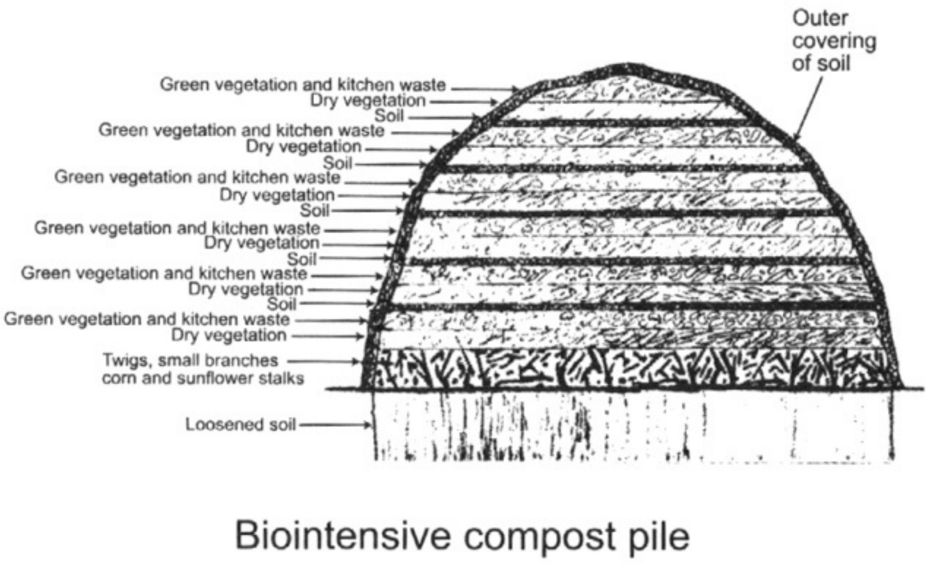


Figure 5. Biointensive compost pile (Yeang & Woo,59.)

8. Design urban areas to reduce the use of ecosystem and biospheric services, such as bioclimatic urban type structures that consider climatic conditions.

9. Design sustainable urban renewal projects for cities that have become polluted through industry and whose natural resources have been damaged.

10. Ecomasterplan with a blue infrastructure -a sustainable drainage system to manage surface water run-offs so that it stays on site; water management and conservation within the built environment. (Yeang, Ecomasterplanning, 24ff.)

11. Create local, regional, state, and national planning policies that regulate development and manage lands on the basis of the ecosystem concept. Ecosystem management would include the integration of ecological, economic, and social principles to manage biological and physical systems that protect long term ecological sustainability, natural diversity, biogeochemical cycles, and the productivity of the land. This approach would recognize that there is no dichotomy between humanity and the environment. (Barker, 1996.)

12. Creation of public policy that addresses the landscape as a whole; recognizes whole farm or whole watershed as one ecological unit. This kind of policy would create soil conservation regulations for not only agricultural land but also urban-rural landscapes. The same is true of watershed protection.

a. Strengthen existing regulations and laws, such as required environmental impact statements that precede project approval; clean air and water laws; pesticide control laws; toxic substances control acts; conservation, forest, coastal, and endangered species laws among others.

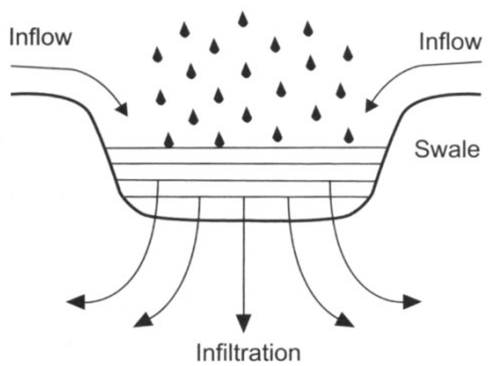
b. New public regulations to correct current imbalances that are detrimental to ecosystem functions, such as gas-exchange, water-purification, nutrient-cycling.

13. Enact take back laws in countries that are not currently have them.

14. Ecosystems treat waste by absorbing detritus constructively back into nature. Ecosystems demonstrate that as biomass increases, more recycling loops and complex interactions are needed to prevent it from collapsing. Design human built environments to contain more recycling loops and interactions. An ecosystem becomes more self-contained as it matures. It circulates what it needs within the system without losing any matter to the outside environment. Using this principle, ecomimesis designs the built environment so that materials are continuously reused and recycled and are more connected to the evolutionary process of life rather than making isolated, disconnected, inanimate objects of consumer natural materials.

15. Design for wastewater and sewage treatment and recycling systems so that waste is treated at its source. This can be done by controlling and integrating human waste and other emissions, capturing storm runoffs, reusing municipal wastewater for irrigation.

16. Design and construction of bioswales, filtration strips, retentions ponds, sustainable drainage (SUDS), lagoons. Rainfall and surface water runoff into bodies of water and the sea can be eliminated.



Use of bioswales for site-water management

Figure 6. (Yeang and Woo, 37.)

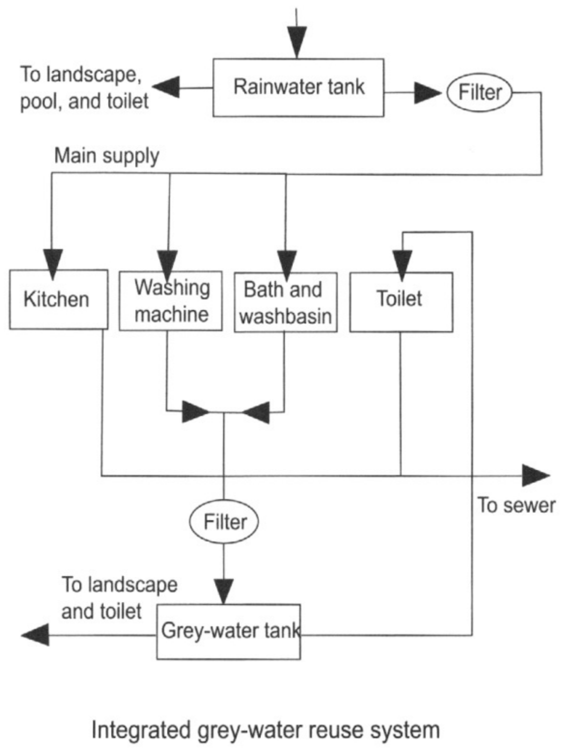


Figure 7. Integrated gray water reuse system (Yeang and Woo, 113.)

17. Construct water holding areas and treatment to return water to it source, decrease runoff, and pollution of bodies of water.

18. Design for water conservation, recycling harvesting, such as rainwater, to conserve water.

19. Design for wastewater and sewage treatment and recycling systems.

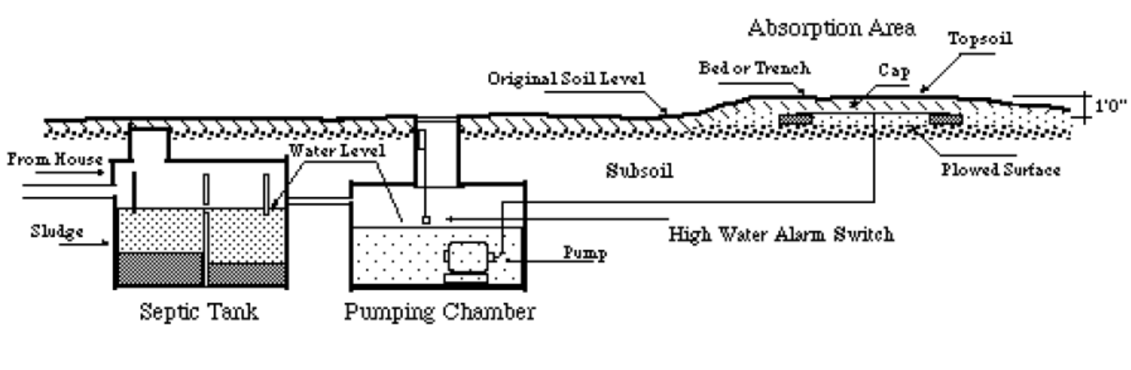


Figure 8. Illustration shallow trench section view (Yeang & Woo, 213.)

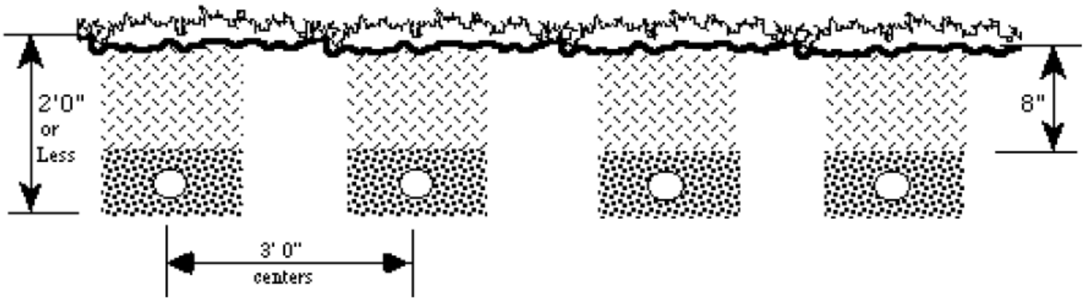


Figure 9.

20. Design wetlands for wastewater treatment, irrigation leach fields, aerobic wastewater treatment (Todd et al. (1996).)

21.Design shallow mound or shallow trench gray water systems

22. Design and use living machines to treat waste ecomimetically. Living machines are living organisms of all types that are housed in a casing or structure made up of lightweight materials. Living machines can be designed to produce food or fuels, treat wastes, purify air, regulate climates of perform a combination of these tasks at the same time. (Tood and tood, 167-176).

23. Utilize solid and hazardous waste treatment-injection wells, integrated waste management, gasification, evapotranspiration.

24. Design environmental restoration of devastated land by using the processes of natural succession. This requires an understanding of the specific ecosystem and the sequence of rehabilitation beginning with primary succession's most resilient organisms that can grow under adverse conditions, the gradual development of food chains that evolve from short simple ones into more complex chains, and recycling of wastes and nutrients This understanding will also improve the economic efficiency of those efforts.

25. Use non-chemical, natural alternatives to chemical pesticides. This would include natural predators and development of new plants that resist pests.

26. Restore and maintain the biogeochemical cycles:

a. Stabilize oxygen cycle by decreasing runoff from agriculture, sewage, paper and textile mills, food processing that increase carbondioxide and ozone at the ground level.
b. Stabilize nitrogen cycle and decrease eutrophication by decreasing use of chemical fertilizers and emissions of greenhouse gases.
c. Stabilize phosphorous cycle and decrease algal blooms and eutrophication by decreasing the use of detergents with a high phosphorous content.
d. Stabilize sulfur cycle by decreasing the use of fossil fuels.
e. Stabilize hydrologic cycle by designing systems that ensure that water remains in the ecosystem of its origin, maintain wetlands, prevent flooding, prevent soil erosion.

27. Design for management of outputs from the built environment and their integration with the natural environment to minimize pollution and maximize biointegration. In an ecosystem, there are no such things as pollutants because the toxins are not stored or transported in bulk. At the systems level they are synthesized and used as needed only by individual species. Toxins are dealt with by organisms in soils with the ecosystems where they are broken down.

28. Design alternatives to traditional farming to stabilize, rehabilitate,and decrease pressures on the soil. Some examples are alley cropping, hydroponic agriculture, aquaponic agriculture, permaculture, building integrated food production.

29. Design for food production and independence. Design to promote urban agriculture and permaculture.

30. Design urban agriculture (Todd and Todd, 118-127.) Design to minimize waste based on the recycling properties of the ecosystem. This would include warehouse farms for cities and suburbs, rooftop gardens, street orchards, bus stop aquaculture.

31. Design ecofarms –diverse interacting components derived from horticulture, orchardry, livestock husbandry, aquaculture, bioshelters, and field crops. (Todd, and Todd, 145-151.) This includes bio-intensive soil management and intensive planting techniques.

32. Ecosystems treat waste by absorbing detritus constructively back into nature. Ecosystems demonstrate that as biomass increases, more recycling loops and complex interactions are needed to prevent it from collapsing. Design human built environment to contain more recycling loops and interactions. An ecosystem becomes more self-contained as it matures. It circulates what it needs within the system without losing any matter to the outside environment. Using this principle, ecomimesis designs the built environment so that materials are continuously reused and recycled and is more connected to the evolutionary process of life rather than making isolated, disconnected, inanimate objects of consumer natural materials.

33. Design for continuity by reducing ecosystem and biospheric services and impacts on the global environment (systemic integration)

This extensive list of ecomimetic designs and activities represent basic starting points for designs that can be done to stabilize homeostasis of ecosystems.

5. Conclusion

This article has focused on the inseparable relationships between the various components of an ecosystem and how human actions have damaged and altered the natural balance of ecosystems. Anthropogenic activities have modified ecosystems not only through industrialization and economic development but also through population growth. As a result, there has been deforestation, desertification, contamination of bodies of water, altered soil fertility, and pollution and global warming from the use of fossil fuels.

The findings cited in this article clearly show that human activities have had seriously negative effects on specific components of an ecosystem: biodiversity, spatial efficiency, and homoeostasis and its subsets of cybernetics succession, and continuity. The findings underscore the combined impact of human activities on ecosystems and their future ability to support an ever growing population without a dramatic change in the way that we design and use our manmade ecosystem.

The discussion of the various aspects of an ecosystem, the effects of anthropogenic activities, and proposed solutions through ecomimesis lead to a simple conclusion: Ecomimetic design can slow the rate at which humans are altering nature for their own purposes. Ecomimesis can also help stem the despoilation of ecosystems and assist in repairing them by adopting natural circular processes rather than linear ones in creating anthropogenic structures and communities.

The notion of ecomimesis and its inclusion of the entire ecosystem and the impact human activities have on the natural ecosystem represents an innovative design paradigm that utilizes both new scientific solutions and respect for the stability of the natural ecosystem. Rather than resolving problems of individual segments of the ecosystem, ecomimesis is a more holistic design approach for the built environment that demonstrates the feasibility of restoring the natural balance in the environment while also meeting the ever expanding needs of society and economy around the world.

Just the Industrial Revolution was made possible and flourished with advances in technology, present day scientific and technological developments can work toward minimizing the climate change and rehabilitating nature that have been harmed by the centuries of industrial development, lack of conservation of resources, and population growth. Creative ecomimetic solutions. such as artificial photosynthesis, non-toxic batteries, and Solar Sewage Walls and living machines to treat waste, are being continually developed and refined by researchers, scientists, and inventors worldwide. Ecomimesis as a sustainable design strategy can be an integral part and major contributor to stabilizing and rehabilitating our natural world at the same time that it addresses the needs of growing economies and populations around the world.

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The Roles of Traditional Markets as the Main Component of Javanese Culture Urban Space (Case Study: The City of Surakarta, Indonesia)

Istijabatul Aliyah[14], Bambang Setioko[15], Wisnu Pradoto[16]

Abstract. Traditional markets function not only as a mere trading place but also as a place for life conception and socio-cultural interaction. In the scope of traditional Javanese city, traditional market is a part of typical basic urban structures and an ever-existing part of the spatial planning pattern of cities in Java, for instance, Surakarta. This study was conducted in Surakarta, which is aimed at investigating the roles of traditional market as a structure component of traditional Javanese urban space. This study is an inductive qualitative research employing several methods of analysis, i.e., Spatial Analysis to find out the interrelationship between traditional market with the structure of traditional Javanese urban space and Interactive-Analysis Model. The results of this study suggest that : 1) Traditional market is a part of typical basic component of a city and an ever-existing part in the spatial planning pattern in Javanese cities. 2) Surakarta as a royal city in Java has a belief related to cosmology world creation namely believing a harmony between microcosm and macrocosm. The basic philosophy employed by Surakarta as a traditional Javanese city is Aturan, Sujud Manembah and Ucap Syukur, and Gede Market is as the realization of philosophy or concept Ucap Syukur. This is very different from the modern urban space by Spreiregen, Krier, and Gallion & Eisner, that macro urban space more emphasis on the physical and economic which will ultimately form the diversity space. 3) traditional market becomes a part of urban space components referring to Javanese cosmology concept in the "Negaragung" zone. and as one of urban space components called "Catur Gatra Tunggal". The concept is very different from the Central Place Theory that proposed by Christaller, that all spatial formations in a city are emphasized more on market driven. 4) In addition, in traditional market networking, Surakarta as one of traditional Javanese cities has special uniqueness by not implementing the Mancapat Macalima concept thoroughly since there is a belief that Wage and Pahing markets' names are irrelevant to be used as traditional market's name, and Gede Market as the main market functions as middle-higher class market.

Keywords: Traditional market, the traditional city of Java, the city of Surakarta Indonesia, Component of Javanese Culture Urban Space

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1. Introduction

During the kingdom era, a city was composed by the existence of big/small settlements, open space (markets, religious ceremonies, public festivals), and streets, which was known as 'Majapahit Complex'. It is strengthened by the presence of several typical traditional Javanese cities mentioned by experts such as Stutterheim, Maclaine Point, Palmier, Witkamp, Van Mook, and Santoso. The variety of typical traditional Javanese cities suggests that traditional markets' component and position occupy a core region of a kingdom called *Negaragung* or the city center (*Note*: Negaragung or Negara Agung : an area surrounding Kutagara, which still belongs to the kingdom's core area since there were authority's land and nobles living in Kutanegara). As a component of traditional Javanese cities, traditional market is anever-existing part of the spatial planning pattern of cities in Java (Santoso, 2008). Traditional market is a part of urban activities' catalysts having various functions. The location of traditional markets occupies a particular area with or without buildings used as the place where the trading activities take place. Sellers and buyers meet at the specified place, at a time set within a certain interval (Jano, 2006). On the other hand, traditional markets function as a node of the exchange of goods and services on a regional basis which then grow and develop evoking various activities in a city (Sirait, 2006).

In a traditional Javanese city, traditional markets have strategic roles, both spatially and non-spatially, namely as the space for socio-culture and socio-economic of the society. At macro level, the presence of traditional markets is a part of the typical basic structure of a city (Adrisijanti, 2000). Moreover, traditional markets located downtown can be seen as a subsystem of a larger economic system to encourage the development of a region and form a circuit round of trade (Sunoko, 2002). The traditional markets having critical roles are usually located in the city centre with higher rank, whereas the supporting markets are located in the suburbs (Pamardhi, 1997).

Unlike the structure of traditional Javanese cities, the urban structure of modern or western cities is marked by the existence of desentralisation, dispersion, and several activity centres, eventually forming a spatial structure which is complex and susceptible to conditions (Anas, Arnott, & Small, 1998). Urban space is generated from the city's surface as the floor and the building's facade as the enclosure. Specifically, a city's features are strongly related to the activities done within a city, thus there are trading city, industrial city, and other cities in accordance with available activity features in the cities (Gallion & Eisner, 1983). Besides, these features will produce a synergy of physical planning and activities within urban spatial planning which gives solid void composition, inter-part relationship, and responsive condition towards the users' needs (Trancik, 1986). Meanwhile, at macro level, modern urban space according to Spreiregen, Krier, and Gallion & Eisner emphasizes more on physical and economic aspects. In other words, all spatial formations in a city are emphasized more on market driven, with the city's service system towards *Central Place Theory* (Christaller, 1966).

In this current era, all regulations related to the provisions of health, education, shopping, and praying facilities are allocated with service distribution consideration which refers to *Central Place Theory*. Various urban spatial planning and development decisions are taken based on service scale principles in accordance with the number of population and the demand of public needs service from social and economic aspects. Meanwhile, cultural, historical and public values do not become the main orientation in formulating urban development planning.

Those situations are completely different from the existing phenomena in traditional Javanese cities. The allocation of facilities and infrastructure in traditional Javanese cities which are particularly related to the main elements (Karaton, mosque, square, and market) cannot be examined by employing modern (western) theory comprehensively (*Note*: Keraton (Javanese: kraton or karaton) is the place where a ruler (king or queen) governed and resided (palace). Based on common definition, keraton often refers to the ruler's palace in Java.). Therefore, urban area development should consider the urban development process throughout a period of time, experiences from the past, and values attached to urban traditional forms towards continuing cities (Sharifi & Murayama, 2013). Consequently, these bring influence on today's free market climate in response to the establishment of Asean Economic Community. All planning forms are orientated towards goods supplies and distribution as well as economic values or market driven. Every strategic position in a city will be perceived as assets which can be developed economically, as a regional node to encourage various activities within a city generating the relations between social, economy and production (Sirait, 2006).

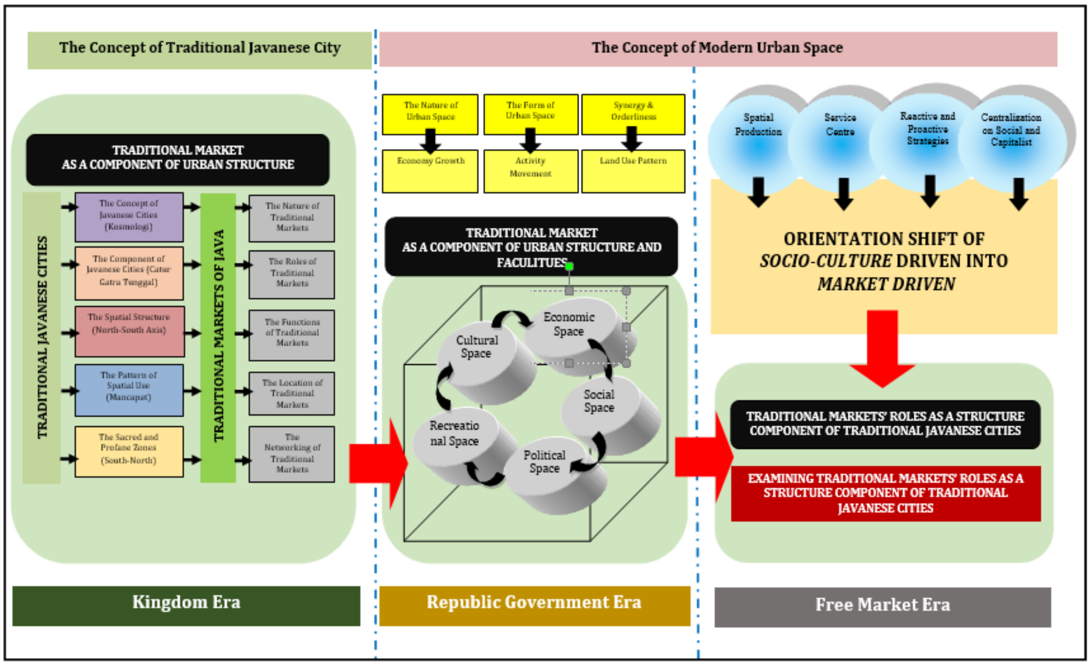

Figure 1. Mindmap and Background Knowledge.

From the above differences, thus, it can be inferred that the concept of traditional Javanese urban space positions traditional markets as cultural product, social function and life conception of Javanese society. Besides, in its development, the concept orientates more on socio-culture or socio-culture driven. On the contrary, the urban space concept based on modern theory positions traditional markets as economic facility and regional trading node, and in its development it orientates more on economy or market driven. Nevertheless, how traditional markets' roles position themselves as a component of the traditional Javanese urban structure has not been identified in detail yet. Hence, it is necessary to conduct a research aimed to examine the roles of traditional markets as a component of the traditional Javanese urban structure. In this case, Surakarta is one of the traditional Javanese cities having specifications and phenomena related to the problems. Therefore, the case study of this research chooses Surakarta as the research locus.

2. Literature Review

2.1. The Definition of Javanese Traditional City

According to several Javanology experts, traditional Javanese city is identical with the terms 'kingdom' or 'kraton' or 'state' or 'complex'. These terms are used differently, but have the same meaning, that is the central government as the city centre. The term 'central kingdom', which is then called 'state', is used by Selo Sumarjan (in Santoso, 2008) to explain that state is a place where noblemen and high class government employees reside. Meanwhile, the term 'complex' is used by Pigeaud to refer to 'Majapahit Complex' as a city comprising a number of big and small settlements which are separated by open spaces and wide streets. The open spaces are utilized for public interests, for instance markets, meeting sheds, cockfighting arena, religious ceremony venues and public festivals (Santoso, 2008). The spatial concept of traditional city in the golden period of Islamic Mataram kingdom is known as *Cosmology* concept in which the region is divided into four parts, namely *kutagara*, *nagaragung*, *mancanegara*, and *pesisiran* (Tjiptoatmodjo, 1980) (*Note*: Kutanegara or Kutagara as the government centre is a palace or keraton located in the kingdom capital. Negara Agung or Negaragung is an area surrounding Kutanegara or Kutagara. Mancanegara is located outside Negara Agung area but it does not belong to coastal area).

On the other hand, in modern context, a city is perceived as a relatively big, populous and permanent settlement, consisting of heterogeneous individual groups as seen from social perspective. City is one of complex human life expressions (Zahnd, 2008). In other words, city is seen as a space experiencing interrelationship processes between people as well as between people and their surroundings. These relationships create land user pattern forming a city structure. Based on urban space classical theory, urban space is formed from a city surface as the floor and building's façade as the enclosure and creates an urban life situation place (Spreiregen, 1965). Furthermore, city is a settlement having relatively big population, limited area, generally non-agrarian, relatively high population density, place for groups of people at particular number living together within particular geographical area by economic and individualistic rational relationship pattern (Kostof, 1991). Meanwhile, according to sociologists, the meaning of city is strongly related to the existence of market, that is a place in which people can fulfill most of their economic needs at local markets. A city's characteristics include the existence of markets as fortress, as well as private law system and cosmopolitan (Weber, 1994).

2.2. Traditional Market as a Component of Urban Structure

As mentioned by Wiryomartono, market as a noun is synonymous with "peken" and the verb is "mapeken" which means to gather (Wiryomartono, 2000). The primary requisite of market formation is there is a meeting between sellers and buyers either in one place or in different places. Market is also an economic element which can bring benefit and prosperity to human's life (Toni, 2014). The presence of market as the media for production and distribution of production output contributes significantly in accelerating working system, mindset and quality of production types. In other words, markets can be an indicator in the change of production, consumption and distribution of certain goods. Some of traditional markets in Java reflect agrarian life pattern and cannot be separated from livelihood's characteristics of the surrounding society (Sunoko, 2002).

Traditional markets particularly located in urban areas have grown in Indonesia since the early settlement or kingdom. In the period of Majapahit Kingdom in 14th century, markets have developed within the city center area which were located at intersections (Santoso, 2008). In addition, one of the Eerste's historical notes (in Adrisijanti, 2000) shows that Banten city had owned several traditional markets in 1646 located in Paseban, Pecinan and Karangantu. In the early growth, traditional markets were in the form of spacious field without permanent buildings (Graaf, 1989). As the time passes by, traditional markets were established in many cities, formed by trading activities which are developed in open and adjacent spaces, fields and roads, and adjacent to settlements. Traditional markets are usually located in strategic places, reachable by both sellers and buyers which are not far from village, inter-villages and safe place from common interference (Rutz, 1987).

Besides, traditional markets have humane characteristics so that they can develop closeness and "kinship" relationship between sellers and buyers. In line with this, Rahadi also suggests that service quality and consumer identification factors play critical roles in encouraging consumers to shop or make a purchase again in traditional markets. Indeed, these friendly and acquainted relationships between sellers and buyers become special characteristics of traditional markets (Rahadi, 2012).

2.2.1. The Roles and Functions of Traditional Markets in Urban Space

Traditional markets grow and develop as a node of goods and services exchange on a regional basis which subsequently evoke various activities in a city. The activities are not only in the form of goods and services exchange or selling-buying, but also information and knowledge exchange (Ekomadyo, 2012). It is in accordance with Geertz's theory which suggests that "market" is an economic principle as well as a way of life, a general style of economic activity covering various aspects of particular society up to socio-culture life aspect comprehensively (Geertz, 1963). In the scope of Javanese society, the strength of economic activity is centralized in traditional markets. Traditional markets function not only as a selling buying place but also a life conception and socio-culture interaction (Pamardhi, 1997). On the other side, traditional markets also reflect the society's life, marked by society's social economy domination as the environment where markets are established (Hayami, 1987). According to Bromley, traditional markets in Asian countries are located in rural and urban areas (Bromley, 1987). Furthermore, it can be figured out that the existence of traditional markets lies on social factors including norms, beliefs and bargain which can strengthen loyal network of market visitors to keep shopping in traditional markets (Andriani & Ali, 2013).

2.2.2. Traditional Markets in Urban Economic System

Traditional markets are seen as an organizational system comprising interconnected and interdependable elements, thus forming a complex unity which supports each other components. In this case, market system includes several components, namely rotation, production, distribution, transportation and transaction (Nastiti, 1995). Traditional markets cannot be separated from many problems, either financial or operational system. The sellers of traditional markets encounter several difficulties, including goods delivery, service and payment with producer or consumer. Besides, there are time and weather problems. Throughout this time, sellers overcome these problems by establishing relationship with middlemen, consumers (sellers) and between sellers, both producers and distributors even with market officers and 'goods carrier'. In addition, sellers always keep working hard, and getting used to thrift habits, as well as religious improvement among seller community (Sutami, 2012).

2.2.3. The Scope of Traditional Market Service

The market system usually culminates in one main central settlement or other centres, which eventually leads to networking among markets. A market is a space or particular area with or without buildings used as a place where selling-buying activities take place. The goods sellers and buyers meet at the specified places, at a time set within a certain interval (Jano, 2006). Traditional markets have become urban public space, a place where society gather and build social relationship between them (Ekomadyo, 2007). In the scope of traditional markets, there is several work divisions including the sellers who manage the goods transportation from one market to other markets, the sellers who manage goods sale to rural area, the sellers who manage goods weighing or wholesale, and the others may sell textiles, baskets, livestocks or corns (Geertz, 1963). On the other hand, the seller's effort to sustain the continuity of traditional markets is to maintain the social advantage created by a business life tradition in traditional markets which becomes the basic reference of conduct for sellers in daily business by preserving values and norms of honesty, trustworthiness, cooperation between sellers and consumers and cooperation among sellers in traditional markets (Laksono, 2009).

In its development, traditional markets reach larger scope as a node of goods and service exchange on a regional basis which then grow and develop evoking various activities within cities (Sirait, 2006). It is supported by the result of Karnajaya's research suggesting that the relocation of traditional markets can change field utilization, street pattern, movement and pattern or type of building, circulation way distribution and land use (Karnajaya, 2002).

3. Research Methods

The research location is the city of Surakarta, particularly Gede Market as a traditional urban component of Surakarta. This research starts with data collection through extracting information by observation and interview, both structured and unstructured, and content analysis (Creswell, 2009).

The techniques employed in collecting data are as follows:

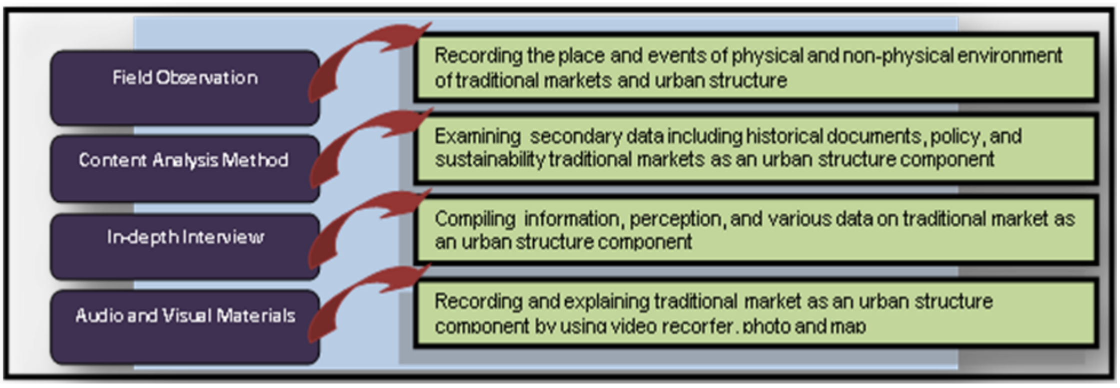

Figure 2. Technique of Data Collection.

The research informants are focused on the market doers, market users, private institutions and policy makers of traditional Javanese urban space. Nevertheless, there are possibilities to expand the involvement of other informants, for instance cultural observers and public figures related to historical data of traditional Javanese cities (Arikunto, 2010). In addition, the technique of data analysis applied in this research is spatial analysis to examine the service scope and networking of Gede Market as a component of traditional Javanese urban structure in the form of diagrammatic map and interactive-analysis method to analyze the roles of traditional markets as a component of traditional Javanese urban structure in the case of descriptive research finding (Miles & Huberman, 2002).

Spatial analysis is conducted in the scope of Surakarta city, particularly in the core part of the city formed based on the traditional Javanese urban concept and Gede market area. Spatial analysis discusses the integration between forming components of traditional Javanese urban space in the scope of city or region.

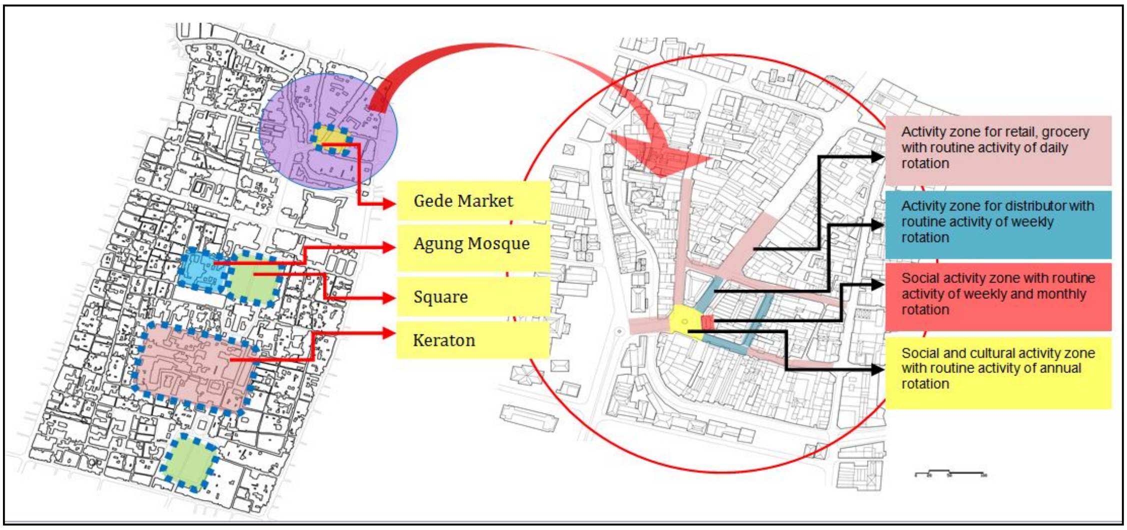

Figure 3. The Scope of Spatial Analysis on the delineation space forming components of traditional Javanese City and Gede Market Area.

Meanwhile, interactive analysis is undertaken by organizing data and elaborating it into units, synthesizing, composing into patterns, selecting which one is important and which one will be examined. This starts before the researcher enters the field, continued when the researcher is present in the field interactively, continuously and thoroughly so that the data is saturated. Data saturation is marked by the absence of newer data or information.

4. Results and discussion

4.1. The History of Surakarta

In the historical establishment of Surakarta Hadiningrat city, as written in *Babad Tanah Jawi*, *Babad Sala* and *Babad Giyanti*, the relocation of Mataram Kingdom from Kartasura to Surakarta was because of the doom of Kartasura Kingdom as a result of Geger Pecinan incident in 1740-1743 (*Note*: Babad is a kind of Javanese text related to the history of Javanese land, Sala or Surakarta city and Giyanti treaty. Giyanti treaty is the agreement between VOC, Mataram (represented by Sunan Pakubuwana III) and Prince Mangkubumi group). Finally, through physical and mystical considerations, “Sala Village” was chosen as the best place to establish new Keraton Mataram. The selection of Sala village was based on the following considerations (Aliyah, 2002):

- Sala village is located near *tempuran*, which is a meeting place of two rivers namely Pepe and Bengawan (*Note*: Tempuran is a meeting point of two river flows).

- The location of Sala village is near Bengawan, the biggest river in Java island which has been known since ancient period having important meaning as the connector of East Java and Central Java and used for the sake of economy, social, politics and military.
- Sala has become a village, thus in order to establish keraton, it is unnecessary to call for forest cutting laborers from other places.
- The meaning of the word Sala is connected with the word *Cala* which means a large room or shed as a sacred building.

Keraton Surakarta was built based on the pattern of Keraton Kartasura which was only wreckage at that time. When the building of Keraton has been built, in the condition that there has not been brick wall fence in the surrounding keraton, Sunan Paku Buwono II pronounced the establishment of Surakarta Hadiningrat Country in 1745. In the process of relocation, several buildings of old kingdom including Pangrawit shed which are now located in Pagelaran were also relocated. According to historical notes and Solo Heritage Society document, this relocation passed Kartasura-Sala street, through west street passing Laweyan Kampong dan Kemlayan Kampong (Secoyudan street) (Aliyah, 2002).

The city arrangement started in the reign of Paku Buwono II in the early relocation of Keraton Surakarta from Kartasura. In this case, Surakarta is centralized in the Keraton Surakarta Sunanate which becomes the central government as well. Meanwhile, the city's facilities including squares, mosques and markets were located in the northern Keraton. Surakarta as a kingdom city in Java has a belief on the effort of cosmology world creation, namely believing the existence of harmony between small world (Microcosmos) and big world (Macrocosmos). This influence can be seen from the governmental system, namely a king as a single ruler (small world ruler). Another influence is the royal area division portrayed as a concentric circle of authority distribution. The first authority is in the most inner circle and the more outer part refers to the less authority. Meanwhile, the area of keraton is the most inner constellation or the first order namely *Kutanegara* (Aliyah, 2002).

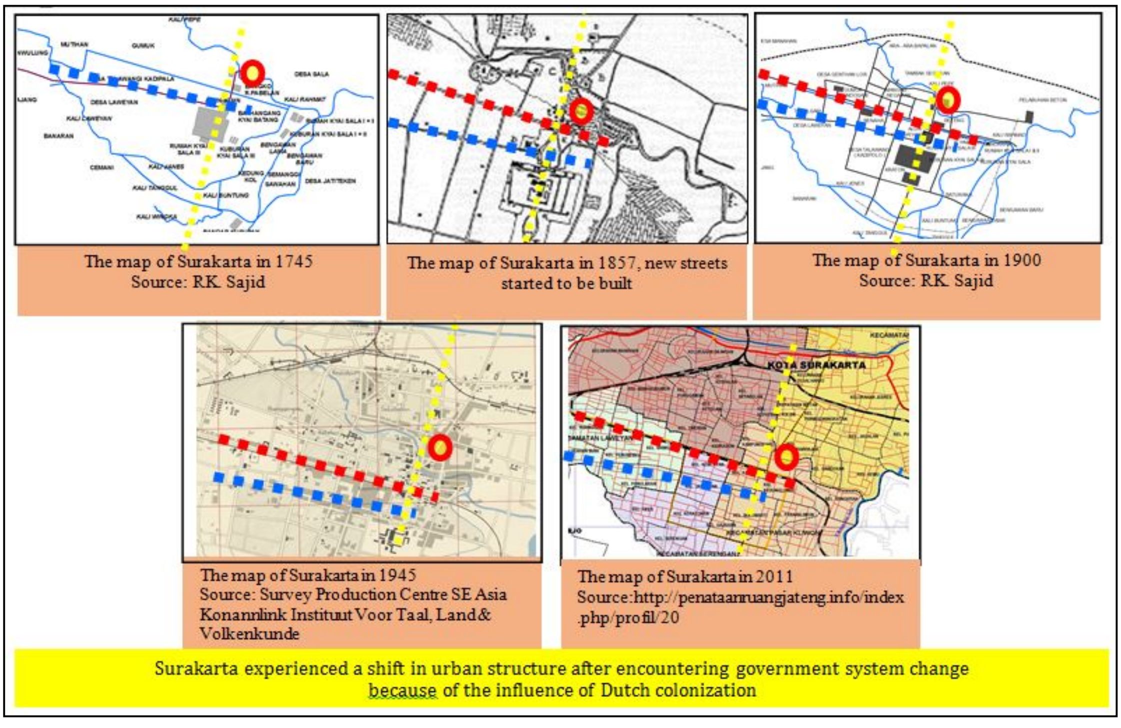

Figure 4. The Map of Surakarta's Development.

According to Figure 4, it can be seen that the development of Surakarta as traditional Javanese city underwent urban structure change in 1745 until 2011. The significant change started in 1857 signified by the construction of a new street namely Slamet Riyadi Street as the main axis (red line) which substituted the previous main street built at early development of Surakarta namely Rajiman Street (blue line). Besides, the street development was not only focused on the main street but also on other parts as seen in the map of 1900, 1945 until 2011. In 1945, it can be seen that various spatial urban components had been built completely. By this development, thus it can be known that the position and role of traditional markets, particularly Gede Market, have no different position namely north south main axis as traditional Javanese axis.

Several prominent characteristics of Surakarta as a traditional Javanese city are as follows: (Santoso, 2008):

1. Surakarta has two squares namely Northern square and Southern square.
2. The complex of keraton is located between Northern ans Southern squares.
3. The relocation of urban area to rural area is quite harmonious. Athough there is no information regarding to the early city border.
4. In Surakarta there is a wide road stretching from the east to the west dividing Surakarta into south and north parts.

The mosque, keraton and the houses of the prince are located in the west part of the city. This part tends to be situated in southwest (Hasta Brata), which in Javanese cosmography refers to a direction having characters from fire that owns strength and divine power and is able to conquer all attempts against universe law.

4.2. The Area Of Pasar Gede In Surakarta

4.2.1. The History of Pasar Gede in Surakarta

One of the traditional markets existed in Surakarta Hadiningrat Kingdom period and becoming a part of urban constellation is Pasar Gede. Pasar Gede is perceived as one of the traditional Javanese urban structures. Besides, before the Keraton relocation from Keraton Kartosura to Surakarta on 17 February 1745, there has been trading activities in the valley areas of Semanggi river, Bengawan Solo river dan Pepe river (Soedarmono, 2004 in Mutiari, 2010). Pasar Gede is one of the plans of PB X and Dutch colonialists to develop economy sector in Surakarta (Mutiari, 2010).

4.2.2. The Roles of Pasar Gede as a Traditional Market in Surakarta's Constellation

In the spatial planning of Javanese kingdom area, especially in Surakarta, traditional markets are situated in the scope of *negaragung* or the city centre which is sacred, or *dhalem* as the centre (*Note*: Dhalem is the residence of noble family). The location of traditional markets is in the scope of keraton, square and mosque (Santoso, 2008). It is also strengthened by the concept of traditional markets' location in Surakarta during kingdom period which refers to the concept of *catur gatra tunggal* (Rajiman Gunung, 1991 in Sunoko, 2002) (*Note*: Catur Gatra Tunggal is four structural components of traditional Javanese city consisting of karaton, masjid, square, market). In this case, the complex's composition is keraton is in the south of square, mosque is in the west of square and market is in the northeast of square (Basyir Z.B, 1987). Meanwhile, the primary components of a city regarding to the Islamic Mataram kingdom consist of the fortress and *jagang, cepuri* and *baluwarti* (*Note*: Jagang is the pit surrounding Keraton. Cepuri is pyramidal-roof buiding surrounding keratin; Baluwarti refers to settlement area for keraton staffs located inside keraton fortress), keraton-square-mosque-market. (Adrisijanti, 2000). It is even emphasized that the location of traditional markets is not merely as physical meaning in the main spatial structure of a city. In fact, traditional markets in the past spatial planning elements have political function as a control element towards social mobility (Soemardjan, 1991).

At macro level, Pasar Gede as a traditional market is a part of typical basic structure of Surakarta. Several typicals of traditional cities in Java portray that traditional market is an ever-existing part in the spatial planning pattern in Java. Various typical structures of Javanese cities have been suggested by Stutterheim, Maclaine Point, Palmier, Witkamp, Van Mook, and Santoso based on Mintobudoyo's information showing that the component and location of traditional markets occupy the main area of kingdom called *Negaragung* or the city centre. Meanwhile, the part of kingdom area located in the periphery is called *mancanagara* (Santoso, 2008).

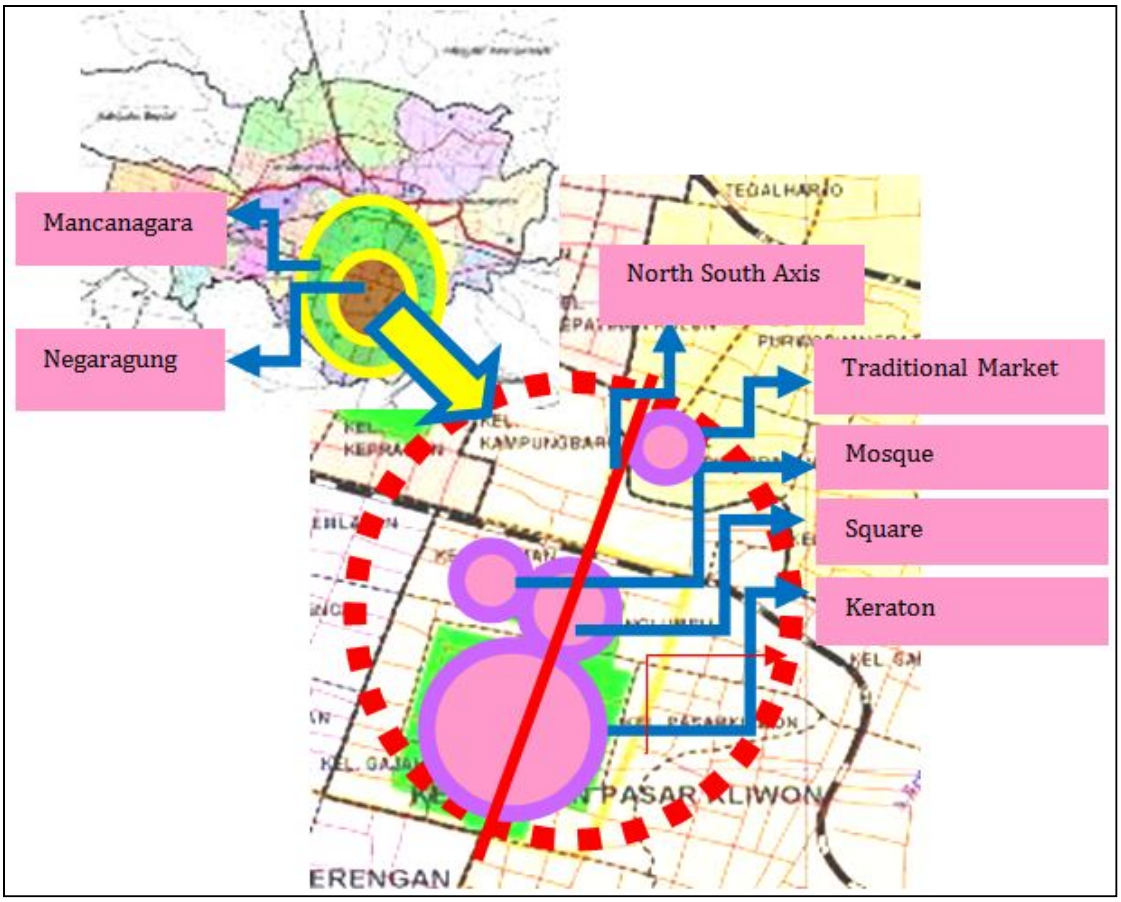

Figure 5. The Structure of Surakarta.

The figure shows that traditional urban space components in Surakarta can still be identified clearly, by each integrated role. More specifically it can be seen from the following table:

Table 1. The Integration of Traditional Javanese Urban Space Components in Surakarta. Source: Researcher's Analysis 2015.

No.	Surakarta City	Components of Traditional Javanese Urban Structure	Analysis of Urban Space Components	Javanese Philosophy
1	Sunanate Keraton	Keraton	As the ruling centre of traditional Javanese concept and values	*Aturan* (Source of Rules and Values)
2	North and South Squares	Square	As a part of keraton which becomes public facility	
3	Agung Mosque	Mosque	As a realization form of intimacy between human and god through worshipping the Almighty God	*Sujud Manembah* (Kneeling down to the Almighty)
4	Gede Market	Market	As an expression of gratitude to God for all basic necessities and food	*Ucap Syukur* (Be grateful of what have been given by God to His worshipper)

4.3. Traditional Markets as a Part of Urban Spatial Component in "Negaragung" Zone

Tjiptoatmodjo mentions the existence of Cosmology concept dividing an area into four parts namely *kutagara*, *nagaragung*, *mancanegara* and *pesisiran*. The part of kingdom area located on periphery is called *mancanagara*. Meanwhile, according to Ossenbrugen, *mancapat* urban structure is derived from the word *manca* which refers to a central point surrounded by four points and each point is located in the west, east, north and south. Besides, based on Witkamp, urban structure is dominated by North South Axis as urban orientation. Maclaine Point also highlights that a city consists of two parts namely sacred city centre and profane periphery (Santoso, 2008). It is supported by the view that a city or *kuta-negara* is a secular and spiritual authority central place and *kuta-negara* citizens are no more than the lord's servants having the role as servants of their ruler (king) with centralized power (Wiryomartono, 2000). Therefore, it can be pointed out that traditional markets as a part of urban spatial component based on the Javanese cosmology concept are located in "Negaragung" zone.

4.4. The Networking of Traditional Markets Based on "Mancapat Mancalima"

Traditional markets play strategic roles in maintaining the growth centre structure. It is shown by the ability of traditional markets in evoking economic activities in their surroundings (Alexander, 1987). In addition, the relocation of traditional markets is capable of changing land use, street pattern, movement and pattern or type of building, equalization in circulation path, and land use (Karnajaya, 2002).

Traditional markets are seen as an organizational system comprising interconnected and interdependable elements, thus forming a complex unity which supports each other component. Meanwhile, market system includes several components, namely rotation, production, distribution, transportation and transaction. It means that 1) The components of rotation are related to production output specifications which eventually determine the cycle of five-day week. In terms of five-day week, there are *mancapat* and *mancalima* systems in Java, namely the role division of a village surrounded by other 4 villages located at 4 directions (*Note:* Mancapat and mancalima are the concept of market rotation known by Javanese society. Mancapat refers to one main village surrounded by four villages located at four directions and mancalima means one main market surrounded by eight directions). Thus, the time rotation division comprises *Legi*, *Pahing*, *Pon*, *Wage* and *Kliwon*. One rotation which lasts 5 days is called a five-day market week and the roles of each market is controlled by five-day rotation; 2) The components of production are related to the path and accessibility of distribution and transportation; while 3) The components of transportation cannot be separated from a market's location which is reachable by sellers and buyers; and 4) The components of transaction are influenced by the preference or selection of a market's location. It is because the more strategic a market is, the more sellers and buyers will come, so that it will optimize transactions which result in the improvement of production (Nastiti, 1995). These are the same with Surakarta in which the networking of traditional markets includes the selection of location based on "*Mancapat Mancalima*" that affects the operational system of traditional markets.

On the contrary, in Surakarta, the implementation of concept "Mancapat Mancalima" is not entirely applied. Based on the interview with one of the rulers of Sunanate Keraton of Surakarta and documents available in Sasana Pustaka, markets in Surakarta applying this concept are Pon Market, Kliwon Market, Legi Market and one main market namely Gede Market. It is because market's names i.e. Wage and Pahing are considered irrelevant to be applied since Wage means limited and Pahing means bitter or unpleasant taste.

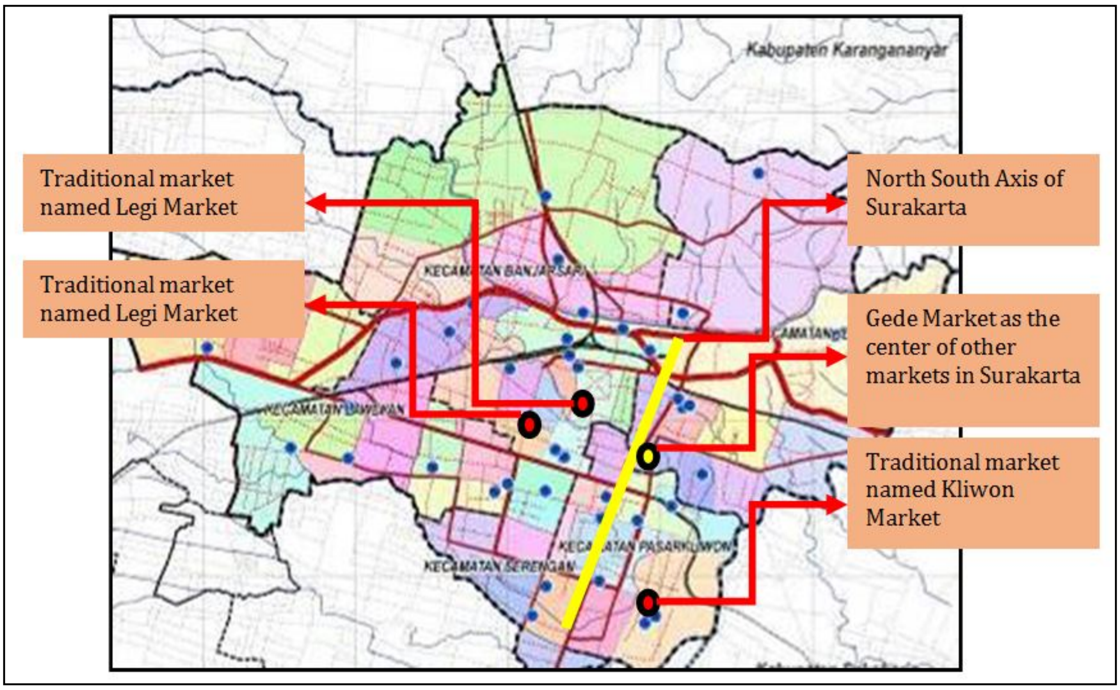

Figure 6. The traditional market networking based on mancapat mancalima concept in Surakarta.

In Surakarta, although the traditional market networking constructed does not implement Mancapat Mancalima concept thoroughly, the networking harmony among traditional markets can be created well. Gede Market functions as the market having the middle to high class segmentation and as the shopping service centre for all ethnics in Surakarta. An illustration of situation in Gede Market area as shown in figure 7 and 8 portrays the situation in Gede Market area during day and night. It reflects that there is not only shopping activity but also social and cultural activity which can be accommodated integratively, particularly in the celebration of Grebeg Sudiro, Babad Kepatihan, and Imlek or Chinese New Year.

5. Conclusion

According to the discussion, thus, it can be concluded that : 1) In the scope of traditional Javanese cities, traditional market is a part of typical basic component of a city and an ever-existing part in the spatial planning pattern in Javanese cities, for instance Surakarta. Traditional market not only functions as a trading place, but also a place for life conception and socio-cultural interaction. It is in line with the results of research Sirait, 2006 stating that every strategic position in a city will be perceived as assets which can be developed economically, as a regional node to encourage various activities within a city generating the relations between social, economy and production (Sirait, 2006). 2) Surakarta as a royal city in Java has a belief related to cosmology world creation namely believing a harmony between microcosm and macrocosm. This influence can be seen from the government system namely a king as a single ruler (microcosm ruler). Another influence is the division of kingdom's territory portrayed as a concentric circle of authority distribution. The basic philosophy employed by Surakarta as a traditional Javanese city is *Aturan, Sujud Manembah* and *Ucap Syukur*, and Gede Market is as the realization of philosophy or concept *Ucap Syukur*. This is very different from the modern urban space by Spreiregen, Krier, and Gallion & Eisner, that macro urban space more emphasis on the physical and economic which will ultimately form the diversity space. Such diversity will produce a synergy of physical planning and activities within urban spatial planning which gives solid void composition, inter-part relationship, and responsive condition towards the users' needs (Trancik, 1986). 3) In this constellation, traditional market becomes a part of urban space components referring to Javanese cosmology concept in the"*Negaragung*" zone. Traditional market physically is as an ever-existing part of urban spatial planning pattern and as one of urban space components called "*Catur Gatra Tunggal*". The concept is very different from that proposed by Christaller, 1966 that all spatial formations in a city are emphasized more on market driven, with the city's service system towards *Central Place Theory* (Christaller, 1966). 4) In addition, in traditional market networking, there is location determination based on "Mancapat Mancalima" as proposed by Nastiti, 1995 that the role division of a village surrounded by other 4 villages located at 4 directions. Thus, the time rotation division comprises *Legi*, *Pahing*, *Pon*, *Wage* and *Kliwon*. One rotation which lasts 5 days is called a five-day market week and the roles of each market is controlled by five-day rotation (Nastiti, 1995). This is which affects the traditional market's operational system in traditional Javanese cities. Surakarta as one of traditional Javanese cities has special uniqueness by not implementing the *Mancapat Macalima* concept thoroughly since there is a belief that Wage and Pahing markets' names are irrelevant to be used as traditional market's name, and Gede Market as the main market functions as middle-higher class market.

Suggestion proposed for further research related to traditional market's role as a part of traditional Javanese urban space is the need of a research analyzing on hierarchy typology and networking system among traditional markets. It is because there will be a thorough knowledge on traditional markets in traditional Javanese city, particularly in the city of Surakarta, Indonesia.

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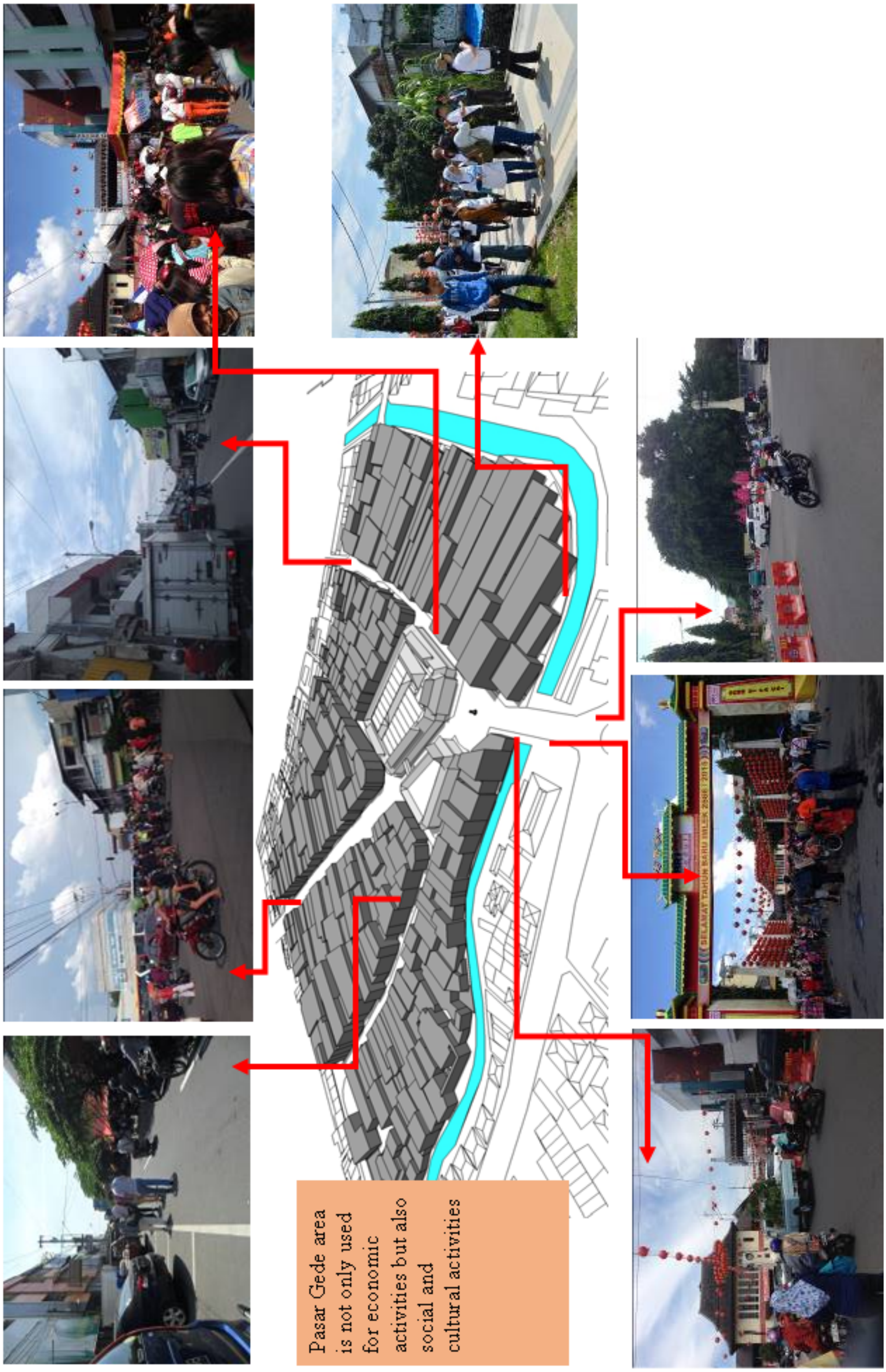

Figure 7. The condition of Pasar Gede area in the afternoon

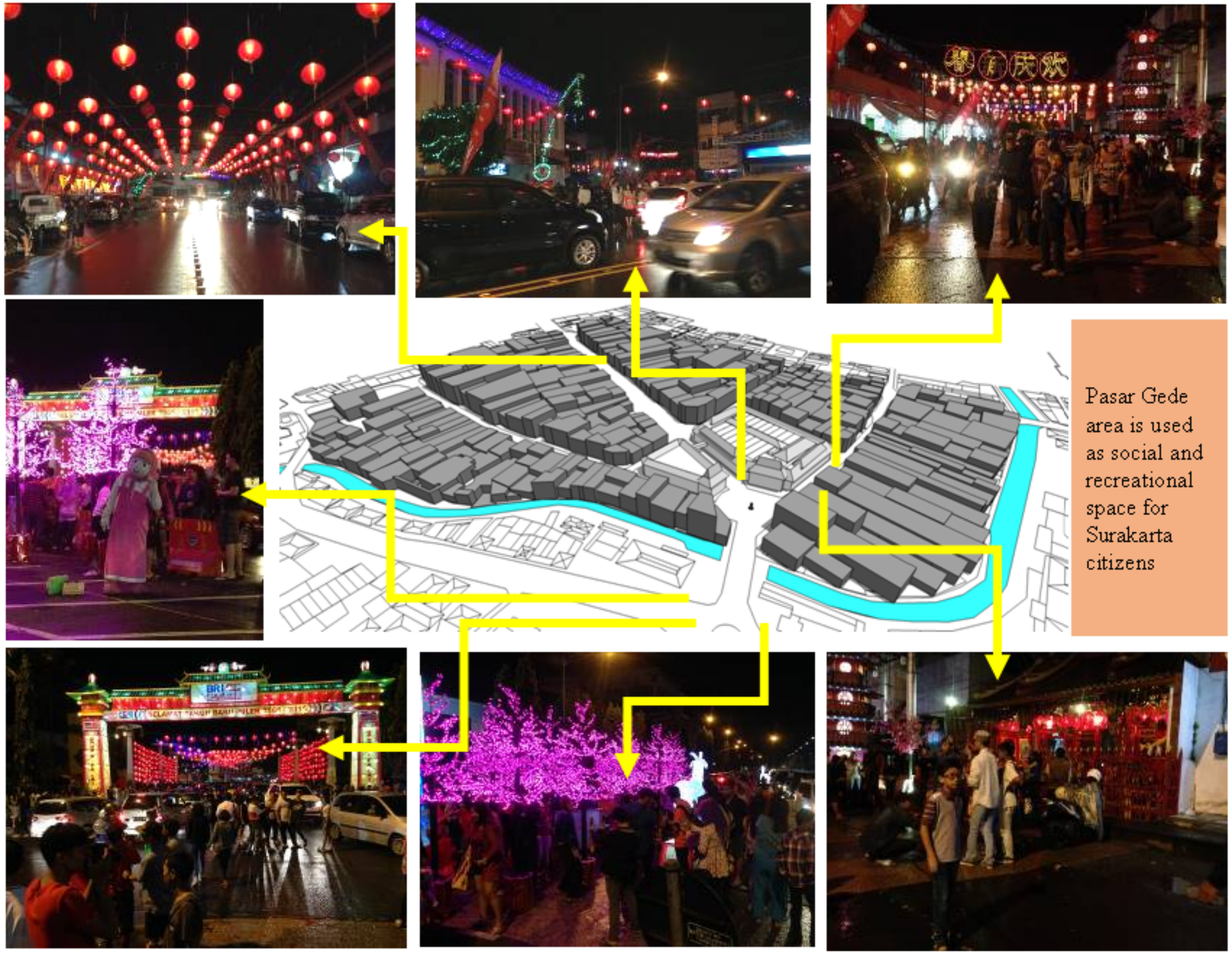

Figure 8. The condition of Pasar Gede area at night welcoming Imlek celebration

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