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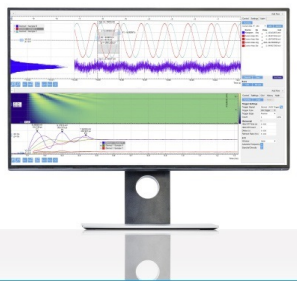

A Synthesis of Tree Retention Studies: A Systematic Review

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Abstract. Massive development has led to the felling of tree in urban areas. Despite extensive scientific efforts directed towards research on tree retention have been conducted, there is a lack of research synthesis conducted in previous studies. This paper offers a systematic analysis of 94 original studies in the 20 years between 1999 and 2019. Literature was retrieved through search in Google Scholar, ProQuest, Sage, Scopus, Science Direct and Web of Science. The aim of the paper was to explore the determinant of the research, context, themes and retention determination, and thus point to gaps and needs in research. Main finding discusses the nearly all studies were conducted in forest settings suggested the future research may provide an analysis of the quality of information related to tree retention in the urban context. The study provides insights into the determinants of tree retention and stresses the need for adequate tree protection during development.

INTRODUCTION

Tree retention is becoming increasingly common at the end of the harvest and is being implemented globally. It was supported by previous studies which highlighted the retention of tree retention as a tool of conservation which involve selecting and marking trees to be retained and removed [1-4]. Retention tree which a tree left permanently standing, also aimed at improving biodiversity because the trees may serve as 'lifeboats' during the regeneration phase for species and processes, as structural enrichment of the re-established forest stand or as 'stepping stones' in a fractured landscape [5]. Similarly, selecting and marking trees to be retained and removed is a fundamental silvicultural practice applied to urban trees management. A. Hämäläinen et al. found that bird diversity was positively related to the total number of mature trees retained [6]. Interestingly, dead trees also essential to be retained in serving food and providing habitat to endangered species [7]. Retention of trees in new developments offers an instant sense of maturity, to the benefit of the project and surroundings in enhancing the scenic character, overall quality of schemes and increasing the values of property. Trees which are essential to human and the environment, and should always be protected and retain to continuously benefit to health and quality of life for people in urban settings.

Research Methodology

Through systematically reviewing and categorizing the relevant literature, these reviews provide a reproducible, objective assessment of the current status of a research field. They included Google Scholar, ProQuest, Sage, Science Direct, Scopus, Web of Science and Google. Keywords used for the search was 'tree retention.' Additional papers are

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found through the database search from the reference list of these research papers. In order to identify original research papers published in English language journals relevant to 'tree retention', scholarly digital repositories are searched. Only papers dealing with retention trees in the research title were included in further analysis. Studies exclusively only included papers in English. Only the duration of the last 20 years (from 1999 to 2019) have been taken into account. Where appropriate, full papers have been downloaded. In a Microsoft Excel database, the following 6 items of information are recorded: (i) author, (ii) journal, (iii) year of publication, (iv) research context (location), (v) research theme, (vi) and retention determinant. Based on the research context, research papers were grouped by study location to determine whether there are spatial variations in the research. Each paper was also classified accordingly to the themes used in the research. Finally, the retention determinant used for each research themes were also recorded. The literature was systematically reviewed using the four search concepts noted below. Our simplified flow diagram is included in Figure 1. Initially, the search of the databases yielded a total of 135 studies. Duplicated studies were removed after which 105 studies remained. Our initial screen of titles and abstracts excluded all studies that did not relate to tree retention. Ninety-nine studies then remained for article review. As a result of the eligibility, ninety-four studies remained to be included in the review.

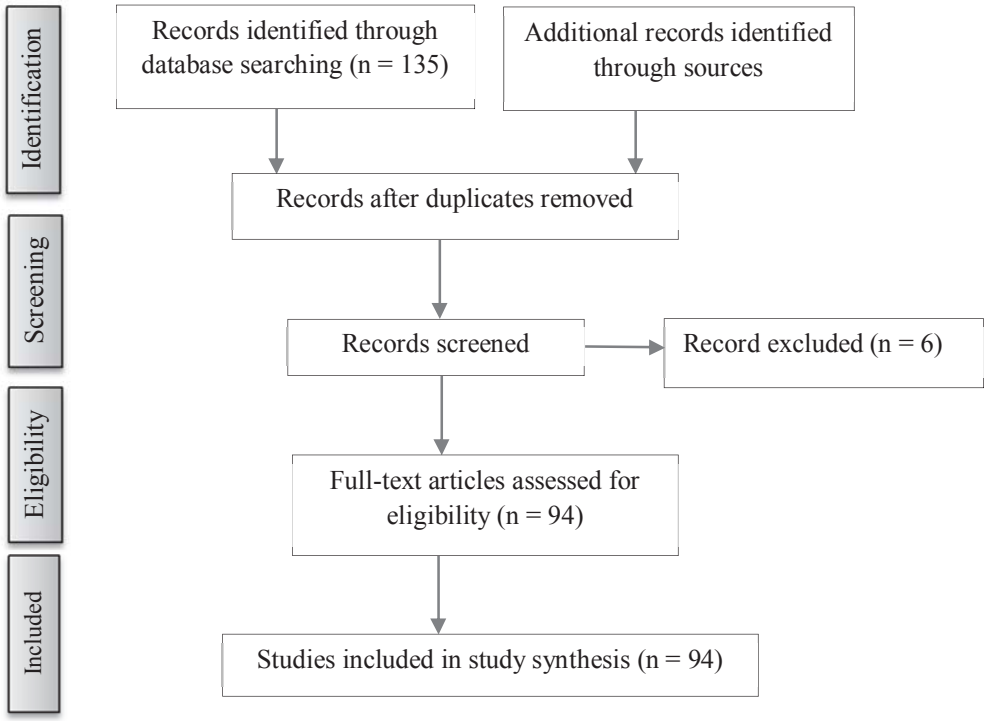

FIGURE 1. A flow diagram of the systematic review.

RESULTS AND DISCUSSIONS

Results

Findings from this research consists of (a) research context, (b) research theme, and (c) retention determinant.

Research Context

A total of 94 original, peer-reviewed research papers on tree retention were published. The articles have been distributed across a wide range of topics in 38 different journals. Two fields, forestry and ecology are dominant. Just over 70% of the articles are published in ecology journals, forestry journal and biodiversity journal. Other field have been represented, such as landscape and urban planning and arboriculture, but their contributions to date have not

been as significant. The result also shows that only six papers (6.4%) dealt with tree retention studies in the urban context which published in the Applied Geography, Landscape and Urban Planning, Urban Forestry & Urban Greening and International Academic Research Journal of Social Science. This concern has been contradictory to highlighting the importance of urban landscapes for improving the quality of life and, retention of trees, especially in urban areas, is merely a new issue that slowly gaining urban attention [8-10]. This view is supported by M. H. Nor Hanisah et al., who writes that knowledge of urbanization and tree cover is essential in order to reduce tree loss during urban redevelopment, thus ensuring sustainable ecosystem services [11]. It can thus be suggested that the study of tree retention is not only concentrating on the forest context but required in the urban context as well. The distribution of tree retention publications varied, with some countries and background prominent than others as shown in Fig. 2. The reasons for the uneven distribution of publications across the countries could be various. The uneven distribution of publications could be attributed to the forestry retention promoted in the Pacific Northwest under the terms green-tree retention (northwest the United States, southwest Canada) in the 1980s before the idea has spread out to other countries [12-13]. Another possible reason was the fact that only English articles were taken into account. A bibliometric review of Scopus, Science Direct, ProQuest, Web of Science, Sage, Google Scholar and Google databases during the period 1999-2019 found a strong English language bias, with approximately 90% of Scopus-indexed articles being written in English. Moreover, the fact that only articles using the word 'tree retention' are taken into account which mostly being used for forest-operation systems research. The research did not, unfortunately, involve related terms such as tree protection, preservation, and conservation, which might be used in other tree retention publications.

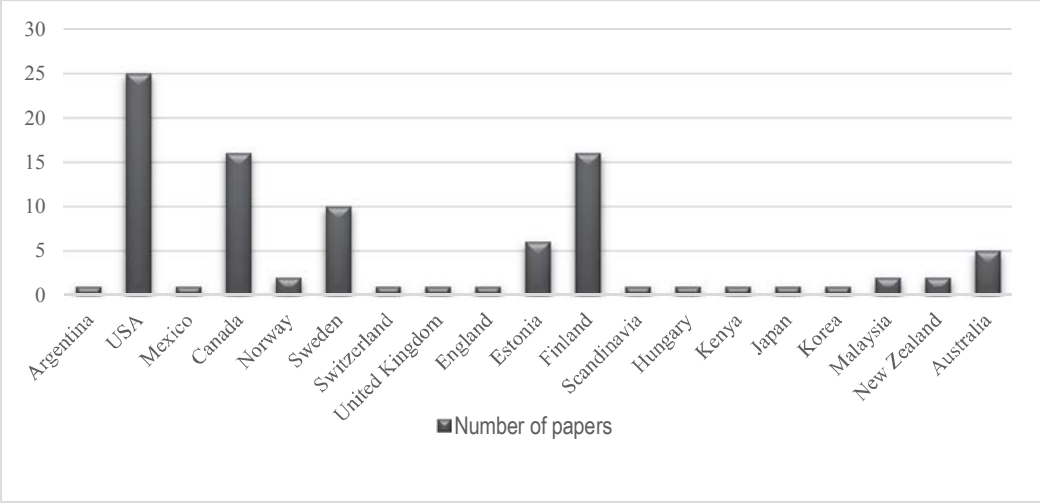

FIGURE 2. Distribution of papers per countries (1999-2019), N= 94

Research Theme

There were three main themes in the articles (biodiversity responses and ecological effects, tree retention management and, sociocultural aspect). Based on the numbers of articles, the overall distribution of study themes showed that researchers preferred certain themes more than others. Biodiversity responses and the ecological effect is the most widely explored by researchers (78 papers) which 83% of the total study on tree retention in 20 years from 1999 to 2019. Only twelve papers (13%) studies about the management of tree retention, including retention planning in urban redevelopment and biodiversity conservation in forestry, while the publication of tree retention research on sociocultural aspect was received less attention by researchers with only 4% (Table 1). The biodiversity papers mostly included papers on assessing differential responses among species groups and direct ecological effects of different characteristics of retention trees. Papers were grouped into four sub-themes, based on the biodiversity and ecological effects such as species abundance and diversity, species survival and vitality, species reproduction and dynamic and soil respiration, decomposition, biomass, and deadwood. Plant diversity papers were the topic in more than half of the papers in the biodiversity and ecological effects group, with the many papers deal with the tree retention system and

the abundance and diversity of species (59 papers). Many studies focus on specific ecological patterns such as coarse woody debris, species abundance, assembly composition or occurrence of some species listed.

TABLE 1: Research themes and sub-theme of the 94 tree retention papers assessed in this study.

Research themes and sub-theme	No. of papers	Sub-theme total
Biodiversity responses and ecological effects		78
Species abundance and diversity	Fauna (32), Flora (27)	59
Plant	18	
Fungi and symbiont	9	
Arthropods	13	
Birds	9	
Mammals	3	
Soil fauna and soil microbial	2	
Other fauna (mix)	5	
Survival and vitality		15
Soil respiration, decomposition, biomass, and dead wood		4
Tree retention management		12
Retention planning and urban redevelopment		3
Retention planning of biodiversity conservation in forestry		9
Sociocultural aspect		4
Perception on tree retention and scenic impact		2
Perception on tree retention and development		1
Perception on tree retention and legislation		1

The urban tree retention planning and socio-cultural aspect were very limited studied so far. In general, therefore, it seems that the biodiversity aspect is only important to be studied in the forest context. As more studies are conducted on this topic, we would suggest that further study is required to show the effect of tree retention on urban biodiversity. Tree management is important in ensuring the retention of local identity. A. Navarro-Martínez et al. concludes that trees provide a strong sense of place and comfort for residents [14]. Trees and landscapes can be shared and organised symbols, symbols of love and encouragement that become part of the identity and characteristics of a place that invokes pride, draws outside interest and encourage economic activity. This view was supported by K. Junninen et al. who concludes that to consider and understand the many interactions between humans and trees that urban trees are important to urban society [15]. However, the limited studies socio-cultural aspect only concentrates on perception-related studies. Hence, more broadly, tree retention study should also emphasize on the socio-cultural aspect.

Retention Determinant

Table 2 presents the tree retention determinant with the description of the consideration factor. It is apparent from this table that there several determinants that have been considered in selecting or influencing the tree retention and removal in a forest and urban context. The results of this stud y indicate that tree retention consideration focusing on the aspect of biodiversity conservation. The tree retention determinant involve are legacy trees, remnant trees, species of trees, size of trees, species composition, aesthetic value, and property scale variables.

TABLE 2. Tree retention determinant in the forest and urban context assessed in this study.

Authors	Retention consideration	Retention determinant	Research context
[16-19]	• species diversity and stand structural complexity • nesting habitat • plant shelter after logging	Legacy tree Species are deep-rooted, Healthy dominant individuals	Forest
[20]	• cultural or economic reasons • potential future use for biodiversity protection	Remnant Trees Officially protected trees, Large trees	Forest
[21-22]	• biodiversity conservation • maintaining particular species richness	Tree species Native or exotic	Forest
[23]	• primary habitat trees • lifeboats	Tree size Tree crown area, Tree hollow	Forest
[6, 11]	• unique assemblages of particular spp. • Birds diversity • create space	Tree height, Tree crown area	Forest and Urban
[24-25]	• habitat and recolonization of species • structural diversity, wind firmness and microclimatic conditions • structural, coarse woody debris	Species composition Dominant and codominant, Structural diversity	Forest
[26-27]	• appreciation • forest cover improvement • public forestry promotion	Aesthetic Mature, Volume, Physical appearance, Location	Forest
[28]	• create space	Property-scale variables Land cover, Spatial, Economic variables	Urban
[27]	• forest cover	The site and land size	Forest

Retaining the legacy trees may mimic the appearance of forests that may produce suitable nesting habitat. Thus, numerous studies on tree retention have attempted to explain the importance of legacy trees in enhancing species diversity, stand structural complexity, and to improve habitat quality. Some published studies by J. Morgenroth et al. and K. Perhans et al. have labelled the trees as important part of society's collective memory that people may develop a sentimental attachment to [29,30]. The results of this study also indicate that the remnant tree as a determinant for tree retention. Remnant trees are predominantly native plant species, provides habitat for fauna and usually having high ecological value. A remnant tree often left standing due to their official protected status for cultural or economic reason. This finding supports the previous study by S. Tönnes et al. which highlight the importance of remnant trees conservation to urban residents' behavior [31]. It is interesting to note that the legacy trees, remnant trees, and native plants species are related to each other, which emerged as the significant tree retention determinant. The retention of particular tree species tends to be more useful strategy to conserve particular species richness. The species of the native plant are considered preferred mainly for environmental reasons (habitat; water retention in the upper catchment; drought tolerant; often less maintenance; and better soil stabilization) and because of their contribution to the development of character and identity of the local identity. Hence, tree retention could be a successful tool for conserving biodiversity if tree species is carefully considered.

The size of the tree also reported significantly as the retention determinant. The larger trees with suitable crown should be retained as key habitat because the trees generally hosted unique assemblages of particular species and function as lifeboats to maturing nearby trees. Generally small tree removal in new development is to create space during demolition and construction activities. However, study by D. F. Shanahan et al. reaches different conclusions, who conclude that although small trees appear to play a lesser role in improving the environment, some may meet the needs of wildlife for food and shelter and provide important ecological values [32]. Another vital tree retention determinant is the planting composition. The main reasons for retaining clumps of trees in the harvested area is to

provide shelter and facilitate species recolonization. The selection of tree groups for retention maximized the structural diversity would improve wind firmness, stability in microclimatic conditions. Moreover, retention of medium-sized trees with a mixed species composition preserves structural diversity and promotes continuity in coarse woody debris.

There are only a few research considered the aesthetic value and property-scale as the tree retention determinant [26-27]. It has been demonstrated that the mature tree, tree volume, physical appearance, and tree location are the significant criteria that contribute to the aesthetic value of a tree. Retention trees in poor condition did not improve the scenic appearance of clear-cut areas and it was noticed that more appealing than undergrowth were mature retention trees. The size, physical appearance, and position affect the scenic value of clear-cutting areas. The stronger the retention trees' health, the more they have been valued, and the visual effects in views are the best problematic toward engendering support for public forestry. The findings also suggest that redevelopment status is the main factor for deciding whether trees have been cut or retained. The removal of the tree is prevalent on higher land value ($/m2).

CONCLUSIONS

We have conducted a comprehensive systematic review of studies addressing tree retention worldwide and a synthesis to understand the research context, research themes covered, and the tree retention determinant. Our findings show that nearly all studies of tree retention were conducted in forest settings while there were very limited urban forest-related publications whatsoever. However, it is often necessary for urban forest managers to retain or replace an existing tree. Therefore, developing knowledge in urban tree retention is important to limit tree loss during redevelopment and construction activities. In general, it also seems that tree retention and biodiversity aspect only essential to be studied in the forest context. As more studies are conducted on this topic, we would suggest that further study is required to analyse the effect of tree retention on urban biodiversity. However, tree retention determinant might have been more useful for tree retention management if the study not only concentrates on the biodiversity conservation purpose Moreover, the studies concerning on socio-cultural was minimal studied so far and only concentrate on perception-related studies. It can thus be suggested that the study of retention determinants should also consider the aspect of socio-cultural benefit and as the important retention determinant in influencing the tree retention and removal in the forest and urban context. As more studies are conducted on this topic, we would encourage further study on the urban tree retention, emphasizing on the aspect related to socio-cultural and integrate the determinant of tree retention to ensure their benefit may be sustained to the people and environment.

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