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FACULTY OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF LAND USE AND IMPROVEMENT

MASTER OF SCIENCES (M.Sc.) THESIS

Assessment of Impacts of recreational Trail Use on Urban Forests: Prague, Czech Republic

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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DIPLOMA THESIS ASSIGNMENT

Phanuel Nana-Yao Gade

Nature Conservation

Thesis title

Assessment Impacts of Recreational Trail Use on Urban Forests

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Objectives of thesis

To evaluate user impacts at three protected public recreation forested parks in Prague.

Methodology

To test the success of two published methodologies hypothesize their success in assessing user impacts.

The proposed extent of the thesis

50 pages

Keywords

urban forest trails; trail impact indicators; vegetation; outdoor recreational impacts; trail degradation

Recommended information sources

Hill, W. and Pickering. C. (2009) Comparison of condition class, point sampling and track problem assessment methods in assessing the condition of walking tracks in New South Wales Protected area . Report for Sustainable Tourism Cooperative Research Centre. Griffith University, Gold Coast.

Kumble, P.A. (2011) Impacts of ecotourism upon cultural and natural resources: an annotated bibliography, journal of landscape studies 4, 81-115.

Marion, J. L., & Leung, Y. F. (2001) Trail resource impacts and an examination of alternative assessment techniques, Journal of Park and Recreation Administration, 19(3), 17–37.

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

Department of Land Use and Improvement

DIPLOMA THESIS RESEARCH

Gade Phanuel Nana Yao

Assessment of Impacts of recreational Trail Use on Urban Forests

2016

Objectives of thesis

This study focuses on the assessing impact of recreational trail use on urban forest environment at three urban forests study sites of Prague in the Czech Republic (Bohnický a Draháňský valley, Ďablice and Wild Šárka forests). Within the study, impacts resulting from outdoor recreational activities will be identified which will be followed by the methodology that will serve as a protocol for periodic assessment impact of outdoor recreation at the three study sites areas. Finally, solutions will be proffered to the impacts assessed in order to protect the health of the urban forests to enhance sustainable and long-term benefit of outdoor recreation.

Methodology

This study employs point sampling with condition class assessment approaches, which is partly measurement based-method/tool and valuation-based method/tool commonly use for assessing ecological impacts. Specifically, the point sampling was used to survey surface condition such as; soil loss/maximum incision and trail width at several sample points along all the formal trail systems of the three study areas with a distance of 50 m between sample points. The same distance was used for collecting common trail impacts such as: the number of informal trails and secondary trails development were also counted and documented. Finally, field assessment of the tread substrates were estimated for each 100m distance along the trail segment. The results obtained will in turn have implications for the understanding of impact of recreational trail use on natural and ecological sensitive environments such as urban forest. The methodology intends to serve as a protocol for periodic assessment of these impacts and protect the overall health of these special purpose ecosystems.

Schedule for processing

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May – July 2014 observational visits to the three study sites

September 2014 and part of July 2015 data collection

October – December 2014 thesis literature review write up

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Keywords

Outdoor recreational impacts, urban forest trails, trail impact indicators, vegetation and trail degradation.

Recommended information sources

1. Hill, W. and Pickering. C. (2009) *Comparison of condition class, point sampling and track problem assessment methods in assessing the condition of walking tracks in New South Wales Protected area*. Report for Sustainable Tourism Cooperative Research Centre. Griffith University, Gold Coast.
2. Kumble, P.A. (2011) Impacts of ecotourism upon cultural and natural resources: an annotated bibliography, *journal of landscape studies* 4, 81-115.
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DECLARATION

I hereby declare that I Gade Phanuel Nana Yao solely authored this master thesis as one of the prerequisite for the M.Sc. degree at the Faculty of Environmental Sciences, Czech University Life Sciences, Prague.

I have carried out different studied connected to my thesis on my own; therefore I declare that I only used those sources that are referenced in the work.

Prague, 20th April 2016

GADE PHANUEL NANA YAO

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This thesis is finally dedicated to the most and invisible God/Jah/Mawu/Nyame for his free gift of wisdom, knowledge and strength for the successful end of the study.

ABSTRACT

Trails are largely considered as a basic infrastructure that provide access to remnant forests areas, which often serve as popular sites for outdoor recreational activities such as; mountain biking, marathon racing and nature tour. With the high population growth in cities, increase in outdoor recreational participation is expected to hike in such natural areas. This can result to severe impacts on trails being; erosion, extensive trail widening and formation of comprehensive braided networks of trails whiles evidencing tread condition problems such as; horse manure or exposed roots. These impacts could ultimately contribute to vegetation fragmentation, habitat destruction, edge effect and introduction of exotic species hence species diversity is pronounced. The study is specifically concerned with assessment of impacts of recreational trail use on urban forest using six (6) formal trails from three popular urban forests in Prague; Bohnické a Draháňské údolí, Ďáblický háj and Wild Sarka urban forests. Two approaches were adopted; Point sampling was used to section the entire trails into 50 m segments and their potential indicators; informal trails (IT), secondary trails (ST), trail width (TW) and maximum incision (MIC), which represents the bio-physical properties of the trails, were documented while walking every 50 m along the entire trail system. After, field assessment of the tread substrates as a proportion of transect width which are used to describe the typical trail system as mutually exclusive tread condition categories were also observed and assessed from 100 m of each segments of all the entire trails. Three potential trail impact indicators were tested and the result; (TW) = ($p < 0.009$) informal trails (IT) = ($p < 0.001$) and maximum incision

(MIC) = ($p < 0.002$) indicating a significant impact of recreational trail use on urban forest. The result was also used to assess all the entire trail system and it shows that Bohnické a Draháňské údolí blue trail experience more impact from users and has the tendency to face severe degradation if there is less intensive management action. Although there was evidence of some managerial actions, yet no clear consistency exists between impact development and intensive trail management. Therefore, the methodology used for this study will serve as a protocol for periodic assessment of impacts that may occur on urban forest trails, whiles future studies would try to focus on spatial data on local physical properties to improve more reliable model of different

factors influencing urban forest trails in Czech Republic and to understand the complexity that exist between different outdoor activities and factors influencing trail degradation. These Spatial attributes would include the location, arrangement, and lineal extent of all informal trails (ITs).

1. Introduction

1.1 Background

The study of recreation and leisure today should be based on its character in the past in order to provide a relevant environment for a continuous research. We can outline the beginning of several contemporary views of leisure and related cultural traditions to the practices of ancient cultures (Kraus, 2012). Nevertheless, the contemporary idea of recreation was more generally created and understood as “leisure” back in the 1920s (Emerald, 2004). During those decades of cultural edge, recreation was viewed as social, economic procedure and ideology that inspires the procurement of goods and services in a greater quantity (Torkildsen, 2005).

Later, after the World War II marked the world’s depression era as a result of ramification of the Second World War; this ultimately created social and economic impacts partly because of short supply of goods and jobs (Cordell, 2008). During that period, people needed a release from a life of hard work and isolation, so leisure time increased causing a substantial rise in human population leading to the onset of outdoor recreational activities (Ibrahim and Cordes, 2008; Siehl, 2008).

Subsequently, the worldwide natural areas recorded a higher number of visitors and it became a constraint to public facilities as the greater population resorted to outdoors to experience their desires. For instance in America, picnicking shifted to rafting and active recreation became traditional and modern (Cordell, 2008). Outdoor recreation then took a new dimension and continuous scene of activities such as hunting, horse racing and tomahawk hurling and related activities became popular together with off-road vehicles, bicycle and hiking (Siehl, 2008).

Nowadays, the meaning of recreation can be varied depending on the approach at which it is perceived by every person and it may include watching television, attending the theater, base jumping, leading the young ones to the zoo and other experiences at outdoors (McLean and Hurd, 2012). This worldwide phenomenon led to the emergence and rise of participation in outdoor recreation activities in natural areas, showing a steady growth up to today while becoming the fastest growing component of the tourism industry in the past decades (Buckley and Pannell, 1990; Buckley, 2002; Newsome et al., 2002; Worboys et al., 2005).

1.2 Outdoor recreation

Outdoor recreation is characterized by focusing its activities in natural or semi-natural environment where users can have contact with "nature or green areas" primarily to either fulfill their regular or weekend task (Silvennoinen and Tyrvainen, 2001). According to Bell and others (2007) outdoor recreation can be developed at national parks, forest, lakes, sea or countryside, sometimes with the mission of staying overnight to engage in numerous activities encompassing natural features. It may range from adventure racing, skiing, cycling, hunting in combination with photographing and camping, horseback riding, running, and hiking, fishing together with canoeing and other related kinds (Ibrahim and Cordes, 2008).

Over the past two decades, the demand for outdoor recreation continued to rise despite the emergence of many new forms of activities (Crandall, 2005). This is due to the excitement that is incurred from participation in nature, being the primary driving force of encouragement for most people who indulge themselves in recreation at outdoors (Gartner and Lime, 2000). This made outdoor recreation an important resource, providing jobs in many different fields of national and local economies, and becoming an essential component of most public sectors (Sandell and Sörlin, 2008).

Moreover, outdoor recreational activities have also the advantage to improve society wellbeing and it is proven that regular exercise greatly averts build up of diseases reducing expenditure on health costs (Bowler et al., 2010; McLeen and Hurd, 2012). However, recent studies found that as participation in outdoor recreation continuous to grow, the youth fall off and rather spend much of their free time indoors playing on the computer or watching TV (The Outdoor Foundation, 2013). Such inactivity affects child development as high levels of child obesity; depression and further loss of attention coupled with hyperactivity disorders are common among children who do not experience physical activities (Martin et al., 2003). This fact was highlighted by the

Outdoor Foundation (2008) that stated that the most passive participants in the outdoors, as well as less active environmental sensitive, are the young population who develop without experiencing adequate exposure in the natural environment. On this note, Tamang (2015) also argued that the growing trend of technology is affecting children's participation in nature and outdoor recreation, as more children are not able to have exposure with natural experiences. This might represent a recent trend related with latest technology advances since similar research stated that children are in fact the most viable participants in outdoor recreation and they are usually found in urban forests environments (Ashcroft, 2002; O'Brien, 2005). A survey conducted in 2013 recorded that approximately 143 million Americans experience at least one outdoor recreational activity (The Outdoor Foundation, 2008 and 2013). In Europe for instance, according to a report on outdoor recreation participation 76 to 91% of the population in the Nordic countries, specifically Denmark, Sweden, Norway and Finland treks to nature forest for recreation purposes once a year (Hannerz, 2014; The Social Indicators in Forestry, 2014).In short, outdoor recreation is now a growing and diverse economic sector with recognized irrefutable economic, social and health benefits that cannot be ignored.

1.3 **Outdoor recreation in urban areas**

In 1950, 30% of the world's population lived in cities, representing less than 50% in 2007 (IUCN, 2014). Presently, as a result of globalization and accelerating urbanization, it is expected that a growth in urban population may increase from 3.6 billion to 5 billion by 2030 and reaching approximately 75% of the worlds inhabitant's by the year 2050 (The world Urbanization Prospect, 2014; Tamang, 2015). All these expansion are expecting to occur in developed nations across the globe (IUCN, 2014). As a result, urban areas are most of the time highly dense, which regularly symbolize burden and a menace because of its insufficient dwelling capacity and presence of concentrated fumes evolving unfavorable atmospheric conditions (Konijnendijk, 2006).

With the high population growth in cities, an increase in outdoor recreation participation in natural areas happened, particular in those located close to the inner cities, such as urban forests. Pouta and Sevanen (2001) stated that a substantial number of people across the globe seek enjoyment in green vicinities and often develop a passion for nature than constantly dwelling in densely populated cities. This means that the use of natural areas for recreation is becoming extensively popular in urban centers, where fragmented natural vegetation patches exist representing an essential element for connecting the people to nature (Leung and Marion, 2010; Newsome et al., 2013).

Nowadays, the uses of urban natural areas have become an attractive target serving a range of recreational purposes (Malmivaara-Lamsa et al., 2008; Pickering and Byrne, 2012). In remnant forests, walking tends to be the most common recreational activity. Other common activities are cycling, jogging, picnicking as well as picking berries and mushrooms (Tyrväinen 2001; De Vries and Goossen, 2002).

Though some people are still doubtful about using these natural areas for recreation because of negative impacts of media information, yet crime statistics have shown very low significance occurrence (Hunter, 2003). This means that people rather preferred built up forest areas which are much closer to community settings for their outdoor recreation because of care and security from the state (Kuo et al., 1998).

1.4 Urban forests and parks as a recreational resource

During the extensive increase in urbanization in the 20th century, urban health concerns emerged and as a consequence, the human and natural world lost contact as a result of overcrowding and unhealthy vicinities coupled with threat situations in most cities of the developed world (FAO, 2005). As a response to these concern's woodlands, different types of trees and special purpose trees were fused into urban environments leading to the appearance of urban forests (Olmsted and Vaux, 1938; FAO, 2011). Thereafter, skills and mechanisms were used to create and manage those areas in order to provide "physiological, sociological and economic" sustenance to the urban community (Jim, 2000; Konijnendijk, 2011). Harrison and Bruna (1999) reveal that structuring the environment as a way of ensuring proper land use in order to meet its present and future demands, yielded urban forestry in Europe and North America during the era of rapid shift in urban inhabitation. Forest patches located in the cities for recreation may also consist of threatened ecosystems like one of the Australia's most important hard wood (*Eucalyptus Piluris*) commonly called blackbut (Pickering et al., 2012) and mouflan (a mountain sheep), which preserve important landscapes in the Czech Republic (Nowakowski et al., 2009).

Europe is largely noted for its culture of preserving and maintaining green-spaces architecture in the past (Forrest and Konijnendijk, 2005). During the medieval period major parts of the old big parks were constructed and owned by the aristocrats and other upper class families (Werquin et al., 2005), who use them basically as hunting fields, collateral security or during times of war (Hunter, 2003). Only 100 ha of the forest land belonged to the municipality at that period (Profous and Rowntree, 1990) but these forests areas were then reconstructed and used for recreation just after the industrial revolution in Europe (Hunter, 2003).

In the Czech Republic with particular focus on Prague, the neighboring woodland was purchased and now handled by the government for decades. Meanwhile, the modification of entire forest area in the city over the last 100 years together with recent classification of those areas has expanded urban forests, exceeding 30% of woodland delineated for recreation (Hunter, 2003). Most of the forests in the urban and suburban area of Prague city soon appeared to belong to special purpose, forest serving both wood-producing function and other purposes, but with the objective of protecting soil and water likewise discharging more social demand (Šebeň,2004). These form the largest essential indicators of "green space" features and they are particularly located in the vicinities of suburban environment (Lesy Praha,n.d). Examples of some of these urban forests are presented in the Figure 1 and include: Bažantnice Satalice, Bohnické and Drahanský Valley, Čimický and Ďáblický grove, Wild Šárka, Hostivařský lesopark, Chuchelský forest, Kamýk, Klánovický forestorest among others (Lesy Praha, n.d.).

Notably, the increase in outdoor recreation in Prague in recent years is becoming more popular partly because of the discovery of many lively forms of activities in the natural areas (Bell et al., 2007). According to Neuman, (2013) and The IUCN World Commission on Protected areas (2014), this increase could also be directly related to urbanization. However, with the rising number of people engaging in recreation in urban forest, extensive pressure might appear on the ecological conditions and other infrastructures such as the undeveloped lands and trails which support recreational use

(IUCN, 2014). Even though, forest or natural areas have such characteristics being trails, campsites and parking lots for supporting numerous of activities, but its extensive use can result to serious adverse effect on the ecological sensitive resources that connect the people to nature (Gartner and Lime, 2000).

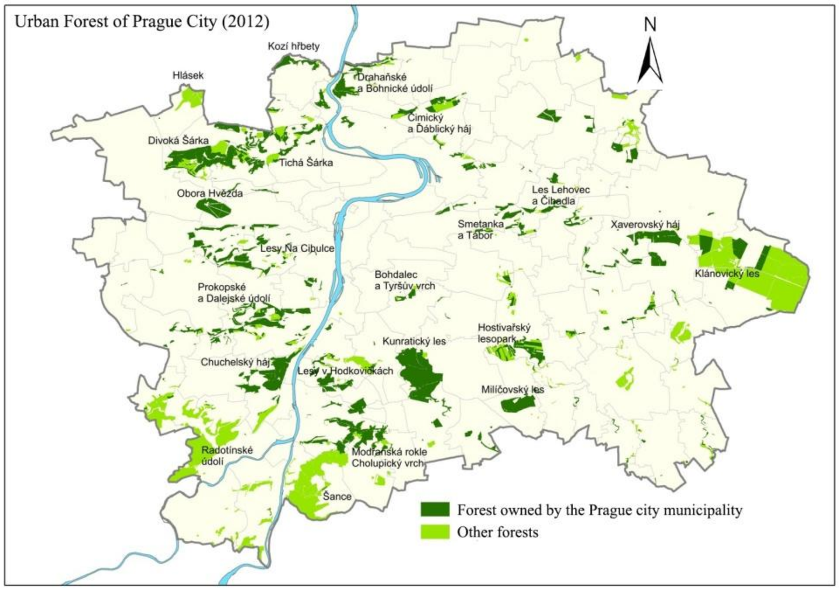

Figure 1 - location of urban forest areas in Prague city (source: Lesni ploch na uzemi hl. m. Prahy, 2012), no scale.

1.5 **Environmental impacts of outdoor recreation**

According to the United Nation Environment Programme (2003), environmental impacts are various activities that can gradually destroy the environmental resources on which recreational activities depend on. With the rising number of people engaging in outdoor recreation in urban forest, there is a potential for different related impacts to occur on sites infrastructures, specifically on trails where most of recreational opportunities are developed (Liddle, 1997). Trail areas are an important infrastructure that allow visitors to access many natural sites such as fragmented or remnant urban forests (Marion and Leung, 2001; Lynn and Brown, 2003; Marion and Wimpey, 2007), and have attracted comprehensive studies around the world (Liddle, 1997; Monz et al., 2010). Despite these trail areas and other green space's ability to act as recreational facility, they also act as a different route for linking communities while controlling pollution and protecting resources by concentrating visitor use (Shafer et al., 2000; Marion and Leung 2001; Conine et al., 2004). The most popular forms of activities include hiking, biking, horse riding, running and motorsports activities (Ballantyne et al., 2014).

Participation in outdoor recreational activities produce significant effects on local resources, hence presenting range of constraints to the environment that restrict leisure enjoyment (Tarrant and Green, 1999; Walker and Virden, 2005). This is important in urban forests, since they represent attractive sites suitable for outdoor recreational events but increasingly developing unavoidable constraint natural resources use, visitor experiences and charged managerial resources (Kuss and Grafe, 1985; Kliskey, 1994). Therefore, all physical, ecological and aesthetic damages that are recognized from trail use and maintenance must be controlled in order to protect valuable resources and not to alter the global stability of urban forests (Leung and Marion, 2000). On the other hand, the impact that may occur from this usual development can pose conditions that affect visitor experiences (Manning, 2007). This means that although some levels of impacts can be overlooked, it is necessary to protect the local ecosystems while providing recreational needs (Hendee et al., 1990).

All these developments on the use of natural areas for recreational activities and related consequences has attracted extensive study worldwide over the past few decades (Liddle, 1997; Cole et al., 2010; Monz et al., 2010; Newsome et al., 2013). As a consequence, recreation ecology (a new subject of research that deals with the scientific study of the ecological impacts of recreation) has slowly grown into increasingly coherent body knowledge. However, until today it still suffers from a lack of attention and there are few scientists devoted to the field of research (Leung and Marion, 2000).

1.6 **Trail impacts**

Trails are usually subject to ongoing impacts that begin to be observed at initial or low levels of use (Farrell and Marion, 2002). These consequences are directly connected to the soil, vegetation, wildlife and water (Leung and Marion, 2000), sometimes air quality. The most widely and frequently highlighted impacts that occur on these components from recreational trail users include; soil erosion, muddiness, trail extension and widening, vegetation damage, and litter together with fire rings (Hendee et al., 1990; Marion et al., 1993;Hammitt and Cole, 1998). Other impacts such as informal trails (user made or desire paths), surface water on trails together with exposed roots, are now a great concern to both mangers and recreational trail users because it reduces the life of the trail and discourages participation (Aust et al., 2005).

Therefore, it is important for managers to know the location, diversity, intensity and extent of user impacts on the trails, variables that determine the degree and nature of the impact (Newsome et al., 2013).From the many potential changes that can be carried on trails, impacts on soil and vegetation have been most systematically explored (Cole, 2004). The impacts on these elements are significantly connected with trampling and trail construction (Leung and Marion, 2000).

Trampling is a potential threat which changes the nature of the soil, its “mechanical properties” and hydrophysical behavior, shifting microclimate of the forest understory (Chatterjea, 2006). This trail damage from users compresses the soil and it loses compaction, leading to increasing trail erosion and trail incision (Leung and Marion, 2009). Besides, it may introduce slow infiltration, which speeds up muddiness on trail. As a consequence, rocks and plant root will be bare producing uneven tread surface on the trail at large (Leung and Marion 2011; Marion and Wimpey, 1996). As this procedure increases with water runoff the most essential plant nutrients are dissociated resulting reduces health of plant and it sometimes becomes a permanent impact (Aust et al., 2005). Furthermore, the compacted soil will show limited root development, because of cytoplasmic streaming, hence the soil becomes incapable to maintain nutrients and growth retardation of adjacent trees is pronounced (Alessa and Earnhart, 2000; Marion and Wimpey, 2011). At a larger extent, the adjacent aquatic ecosystems in the forest are affected by “sedimentation and turbidity” from the runoff or erosion of the eroded trail (Fritz,. 1993). This is very much connected with the findings of Tomczyk and Ewertowski (2011), who identified multiple tread formations and root exposure as a consequence of trail degradation. According to Aus and others (2005), damaged or exposed roots reduce the health of the vegetation and can become a threat to trail users while it impairs the aesthetic value of the recreational forest experience.

Regarding effects on vegetation, when trails are constructed and maintained plant species composition are significantly affected (Leung and Marion, 2000). Besides, as hikers or walkers venture off the trails plants can be bruised, crushed, sheered-off and even uprooted ultimately. These modifications mostly cut down plant vigor and regeneration ability (Malmivaara-Lämsä et al., 2008). Further, pronounce changes to soil microbiology are noticed from the boundary of the forest to the remote part of the vegetation as well as from the trail to the untrampled sites. These disturbances decrease both the vegetation structure and soil composition (Pescott and Stewart, 2014). Recreational trails that serve as a corridor for community stimulus as well as the individual visitors usually document high species diversity closer to the trail. This is as a result of shift in environment, where trail network becomes a route for species movement (Hull and Kuss, 1989). Such understory vegetation protects the trail from soil loss, width expansion and vegetative cover. However, these qualities can only withstand low level of trail use, hence less degradation and declines considerably at high level of use (Cole, 1988).

Furthermore, the use of urban forest trails causes varied disturbances to wildlife species such as: direct and indirect mortality and stress behavior together with avoidance behavior leading to reduce reproductive ability (Purdy et al., 1987). Visitors on trails scare some animals away from their habitat while other animals become attracted by human presence to access human food (Hellmund, 1998). A related published research also emphasized alteration of wildlife habitat from trail users, unfortunately such disturbances recorded wildlife harassment, increasing loss of habitat (Leung and Marion, 2000). A study conducted in a dispersed and non-motorized recreational area revealed decrease in number of native carnivores while recording fluctuation from native to nonnative species composition a community (Reed and Marelender, 2008). Clearly enough, presently, bird-watching and day-hiking may displace wildlife species greatly as less understood in the past (Snetsinger and White, 2009).

The trail grade form is an essential component necessary for protecting the health and stability of a trail system, thus unconstructed trail treads encourages proliferation of unauthorized trails. This means that unplanned and user-created trails will have negative impacts upon soil and vegetation as a result of erosion and destruction of vegetation. Other studies argue and emphasize that the onset of trail expansion begins with single path; it widens and erodes developing into secondary trails and finally forming network of braided eroded trails (Lance et al., 1989; Leung and Marion, 2000). One must understand that, usually, it is much slower to recover portions of badly damaged user created trail than the time take to deteriorate (Ebersol et al., 2002). Informal trails can be created by hikers or walkers, horseback riders and off road vehicles; observed impacts from this type of trail creation are significant. From the context of several studies, these activities are highly connected to proliferation of new and unauthorized tracks or informal trails, which results in the loss of vegetation and displacement of soil (Aust et al., 2005). One thing to note, though quite complicated, evidence of human disturbance connected to user created trails virtually discourages participation, because as it corrupts aesthetic feeling, it is as created by same visitors (Lance et al., 1989; Aust et al., 2005).

Another important impact, though less popular in many recreational ecology studies, indicates the level at which trail use can cause considerable damage to the landscape. For instance, unrestrained activities on trails develop into build-up of networks forming isolated patches in adjacent forest during outdoor activities (Lindenmayer and Fischer, 2006). This formation of trail network result in habitat disruption at sensitive areas, hence altering species diversity, maturing into fragmentation and edge effect ultimately, reduces the health of the urban forest (Pickering et al., 2012).

Several other published articles also revealed that maintaining bad trails contribute to vegetation patches (Fenu et al., 2011). These disturbances reduce sustainability and discourage participation in outdoor recreation. In this light, management duties and responsibilities at various “sensitive” locations can also develop impacts such as improper physical construction, which could mean off-site and on-site management planning. (Kumble, 2011) Exactly in line with the complexity of “physical, ecological and aesthetic” developments that appear in structuring overused trail, observed to be one of the biggest outstanding impacts in natural areas (Leung and Marion, 1996). Correspondingly, Cole (1981) harmonized that recovery management actions in recreational sites can for instance open up trees and shrub canopies and change drainage design, regenerate different species habitat and incising slope above the trail to other locations. From the context of the study, such inadequacies do not maintain the integrity and habitat function of recreational sites (Cole, 1981).

Multipurpose trail use is increasingly becoming popular and diverse globally. Some research studies, though limited, have identified some materialistic trail damage such as uncontrolled dog and horse manure together with littering (Moore, 1994). According to the study, such reckless and irresponsible behavior damage trails though in a short period, yet disrupt other users' experiences and can expel majority of trail users from the popular trail (Moore, 1994). Leung and Marion (2000) confirmed that litter has a strong negative effect on the recreational experiences of trail users. This corresponds with Floyd et al. (1997), who emphasized that such temporal experiences can completely put-off visitors from recreational participation.

At the lager extent, it can also cause massive damage to trails when users abandon a particular recreational site, because extensive environmental impacts occur when there is little use (Kuss et al., 1990). The idea here is that initial trail users may cause the greatest damage to soil and vegetation. This situation can conflict between concentration and dispersal trail use, which can then generate conflict among different users. The present study does not focus on that, but what is important to understand is that dispersing trail users to other unused trails comparatively increases different dimensions of impacts to the existing trail system.

1.7 Methods for assessing impacts on trails

Several studies presented numerous approaches or techniques to assess recreational impacts development but specific technique is yet to evolve (Marion et al., 2006). Three methods are frequently used and proved; *condition class surveys, track problem surveys and point sampling methods*. They include different techniques and produce different indicators to identify variety of data that are required for diverse management plans and decision (Hill and Pickering, 2009). Considering recent recreational and monitoring advances each of the methods can be integrated, (Figure 2) though their advantages and limitations vary considerably, yet they interlink to help monitor trail impacts (Marion, 2006).

The Point Sampling Method assesses trail conditions at transects established at a fixed interval, following a randomly selected first point (Cole, 1991; Marion and Leung, 2001). This method systematically and quantitatively measures selected impact-indicators related to changes in the environment. The techniques show the relationship between recreational use and impacts occurrences, hence recreational ecologists usually adapt it. It can be incorporated into other assessment methods for temporal track monitoring, spatial track monitoring, and detailed track assessment and condition class assessment that require less surveying (Marion et al., 2006; Hill and Pickering, 2009). It identifies three potential parameters/indicators for assessment, though can vary depending on the site condition: the trail width, erosion, informal or user created trails. The two methods have documented to be more effective and efficient as a methodology for assessing and monitoring trail resource conditions (Hills and Pickering, 2009).

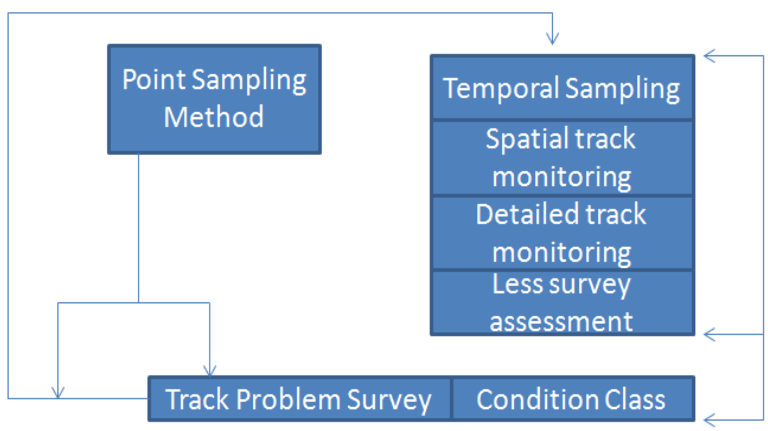

Figure 2 - The figure below illustrates the point sampling relationship with other methods; It shows how point sampling can be integrated into other approaches during planning and monitoring of trails. (Adapted from: Marion et al., 2006; Hill and Pickering, 2009)

The *Track Problem Survey Assessment* indicates the location and length of segments of trails where the identified impacts are occurring. This technique inventories trails by counting and tallying identified problems on the trail together with their location and overall trail length (Marion et al., 2006; Hill and Pickering, 2009). However, this technique is not practicable for continuous temporal monitoring but can be used to measure severity of indicators such as: width, muddiness, running water on trail, erosion, root exposure, and the number of user created tracks (Marion et al. 2006; Hills and Pickering, 2009). On the other hand it may require subjective conclusion from the start of exact damage location to undefined point on the track in order to concentrate resources for maintenance (Leung 1998; Mendel and Marion et al. 2006; Newsome 2006).

The *Census based Survey Technique* assesses qualitatively the entire segments of the trail system. It identifies two approaches: *rapid condition class* survey sections the overall trail into equal segment and allocates them to the identified class condition to each segment (Hill and Pickering, 2009). Basically, this technique measures and identifies trail segments and classifies them as damaged or not damaged depending on severity (Root and Knapik, 1972). Different sections or segments of the trail depend on the environmental conditions; each track is estimated as percentages and can vary depending on the class condition or level of damage/impact (Marion et al., 2006). Condition classes are established based on the amount of disturbance of vegetation and litter, width of track, depth of soil erosion, presence of wet soil and running water, root exposure, and multiple tracks (Hill and Pickering, 2009).

Therefore based on these approaches *point sampling* and *condition class assessment* was chosen for this study. These two approaches were chosen to provide reliable data for characterizing and monitoring continuous trail attributes. *Point sampling* can produce a more precise measurement of trail attributes that occur frequently, such as the width of the trail and soil exposure. Thus, integrating *condition class assessment* with *point sampling* is based on its prime advantage of convenience and easy interpretation of data. Hence, the variable data that would occur across specific sites can easily be presented. These impacts represent general trail conditions, unlike other methods, such as stratified point sampling that selects and records only the length of trail segment impacted (Hill and Pickering, 2009). *Point sampling* surveys the surface condition at several points along the track. Therefore data obtained can easily be influenced by management because it reveals the general condition of the various trail parameters (Marion et al 2006; Hill and Pickering, 2009).

1.8 **Study Aim**

Impacts recognition at various recreational sites clearly becomes undesirable depending on targeted management goals and objectives. Therefore, impacts that actively disturb the behavior of an ecosystem need much attention, primarily because their ability to recover is much slower (Cole, 1990; Leung and Marion, 2005). It is crucial to understand that trail impacts is always longer at initial stage of development, thus degradation occurs quicker than recovery and it can depend on the differences of varied ecosystem (Cole, 2004). For that matter, greater research is desired on how to minimize impacts and fully protect the health of the ecosystem, while stimulating human relationship with nature (Hansen et al., 2002).

This study therefore tries to develop a methodology based on current several studies to serve as a protocol for a periodic assessment of impacts that are usually developed on urban forest trails as a result of diversity of recreational activities. In particular, it applies a condition class survey method on trails of three different urban forest of Prague. As such the study is an important contribution to assess the urban forest trails conditions using the current methodological approaches.

1.8.1 Research questions:

- Does outdoor creation participation actually cause impact to urban forest trails?
- Which component/indicators of urban forest trail are likely to be affected during outdoor recreation and why?
- Do users of the trails for outdoor participation cause impact to the urban forest habitat?
- What is the general condition of the urban forest study trails?
- Which urban forest trail has highest impact from users and why?
- What are the likely environmental/ trail management techniques that can be employed to reduce trail degradation? Or is there any existing management practices that could minimize trail damage from users?

- What would be the relative variability of all the studied trails during management strategies?

2. Methodology

2.1 Study areas

Covering about 1/3 of the territory, forests present a unique and critical component of the environment in the Czech Republic fulfilling a variety of functions. Forests in the Czech Republic are divided into productive and non-productive. Some of the best examples with a strong predominance of non-productive functions are presented in the city of Prague, representing forests with strong recreational function and generally are declared public interest (Act no. 289/1995 Coll).

With the intention to achieve the proposed objectives of this study, three study sites located in the city of Prague, the capital of the Czech Republic, were chosen (Figure 3). These areas are: Ďáblice forest and Bohnický and Drahanský Valley and Wild Šárka. The three sites were selected from different locations within the city and present different ecological characteristics between them (Table 1). The three urban forests were chosen as study area due to its special purpose features and easy access by the general public. The forests are preserved with more than 30% of wood and varied recreational facilities detailed in each of the site characterizations below.

Figure 3 - Location of the three study sites: Ďáblice forest; Wild Šárka; and Bohnické and Drahanský valley.;

Table 1 - Prague city characteristics (source: World Meteorological Organization)

Altitude	177-399 m above sea level
Annual temperature (1961-1999)	Min: 3.6ºC Máx: 12.5 ºC
Annual precipitation (1961-1999)	525.8mm

2.1.1 Ďáblice Forest

Ďáblice Forest was first described in historical writing in the middle 13th century (Lesy Praha, n.d). Today it is owned by the Red Cross and is a State asset and maintained by Department Of City And Green Waste Management in Prague city Hall. It is situated 12 km from the center of Prague at the top of Ládvi, a suburban neighborhood of Prague, specifically between Kobylisy and Čimice. The two existent trails marked as yellow and green attracts outdoor activities such as biking, hiking, running, and even promoting spontaneous outdoor activities among children (Figure 4). Also, there are number of facilities that are situated to increase this location's recreational function, notably: fixed wooded benches pavilions or gazebos and a minor health resort established for relaxation.

The land form of Ďáblice forest appeared to be considerably gently rolling plains characterized by grass vegetation with mixed structure of forest trees reforested with spruce back in the beginning of 1780s (Lesy Praha, 2012). These characteristics have presented essential recreational features to the natural forest and its trails. However, the trails have become crucial for study, because of high use of the urban forest for contemporary recreational activities. Several characteristics of the site studied are presented in Table 2.

Figure 4 - The location of Ďáblice Forest between Kobylisy and Čimice at the top of Ládvi with its formal trail system and marked trails

Table 2 - Summary of Ďáblice Forest main characteristics

Location	501202231N, 14.4854886E
Size of area	62 ha
Forest area	56.2 ha

Species and habitat	Sessile, oak, larch and small leaved lime
Non-forest area	5.8 ha of meadows, water-bodies and roads
Length of trails	Green trail - 1337.4 m Yellow trail - 3794.9 m

2.1.2 Wild Šárka

This recreation area is located 24 km from the center of Prague and comes up with the red tourist trail, which begins at the last tram stop Nádraží Veleslavín. Wild Sarka urban forest runs through Nebusice, valley Litovická-Šárecký stream Jenerálka, Babu, around the tank Jug and returns to the Sarka forest (Figure 5).

Figure 5 - The location of Wild Šárka with its formal trail system and marked trail.

The area is made up of a landscape mosaic, with partly maintained fragments of steppes, and semi-natural vegetation from extensive forest, thus heathlands ecosystem with pastures and meadows representing remnant of thick old growth forest with features of warm and dry climate and other site characteristics (Table 3).

Wild Šárka is perhaps the most frequently visited natural area in the city of Prague because of its romantic and beautiful steep cliffs and canyons with an elevation ranging from 70 to 155 meters. The natural area is established with basic outdoor facilities such as pavilion playground and structured wooden benches, which attracts outdoor participants for trail running and jogging, hiking and nature walk.

Table 3 - Summary of Wild Šárka main characteristics

Location	50.0926817N, 14.3245947E
Size of area	249.24 ha
Forest area	219.3 ha
Species and habitat	Sessile, oak and beech
Non-forest area	29.94 ha of meadows and roads
Length of trails	Red trail - 8083.4 m Yellow trail-3794.9 m

2.1.3 Bohnický and Draháňský Valley

This ancient forest dates back to the Stone Age, approximately 5 500 years ago, and is situated on an old landmark of a rocky promontory fort nad Vltavou Chateaux. Its landscape appeared to be greatly influenced by agriculture activities in the past and reforested with species of trees outlined together with other site characteristics in (table 4). Largely, its vegetation represents a remnant of rocky steppe, heathlands; semi-natural vegetation from extensive forest and naturally outspread with oak and sycamore winter, which is traditionally maintained by regular grazing. The urban forest's geomorphology is made up of three deep valleys with 4 km length of stream (Bohnický creek); covering 6.7 km^2 catchment area and currently part of protected areas. The Bohnické and Draháňské Valley can be found 16 km from the central part of Prague or by ferry from Suchdol to its attractive and historical Slavic settlement and can be accessed by several trails (Lesy Praha, n.d). The popular trails are marked as blue trail and natural trail as yellow in figure 6.

Figure 6 - The location of Bohnické a Draháňské Valley at East-West along the northern edge of Prague

Table 4 - Summary of Bohnické and Draháňské Valley main characteristics

Location	50.1292222N, 14.4196678E
Size of area	90.8 ha
Forest area	84.05 ha
Species and habitat	Winter and summer oak, black locust
Non-forest area	6.8 ha of meadows and roads
Length of trails	Blue trail- 1302.426169 m Natural trail - 1799.273581 m

2.2 Data collection and techniques

The fieldwork was conducted during two distinctive phases in order to cover different periods of the year and its seasons: October 2014 and March 2015.

The biophysical data (trail impact indicators; informal trails, secondary trails and trail width together with maximum incision) were collected whiles surveying the entire trails.

Finally, field assessments of tread substrate as a proportion of transect width of the entire trails were made. This assessment usually defines the trail system as mutually exclusive tread condition characteristics. These trail system substrates include; root and rock exposure, running water on trail, muddiness, human placed gravel for stabilization, damage to existing vegetation, loose or eroding soil, litter or other trash/waste, and other elements noted.

These trail system substrates, including the above mentioned biophysical indicators, were collected from a total number of six popular recreational trails from the chosen sites, which are classified as touristic trails by the Czech Tourist Club (KČT) and thus, are the most popular trails and more heavily used. Hence, the biophysical indicators collected from each trail represent the health or condition of the selected urban forest areas (Marion et al., 2006). These conditions were confirmed and established during several observational visits to the study sites before the fieldwork phases of this thesis research. Afterwards, an extensive survey of trail conditions were made using two approaches as cited in the literature; *condition class assessment* with *point sampling*.

For the data collection, it was considered a 50 m range between each sample point within the selected trails to assess direct and indirect impacts from different trail use and 100 m for collecting the tread substrates as shown in figure 7. Different distances were adopted because related studies documented trail impacts are usually inevitable within half kilometers on trails. In this order, the total trail length was sectioned into segments of 50 m and a line (tape measure) was stretched out from the sample point transect to the both directions, perpendicular to the trail tread for determining the trail width and maximum incision. After, it was considered 100m along the trail segment for recording the tread substrates which determined their condition characteristics.

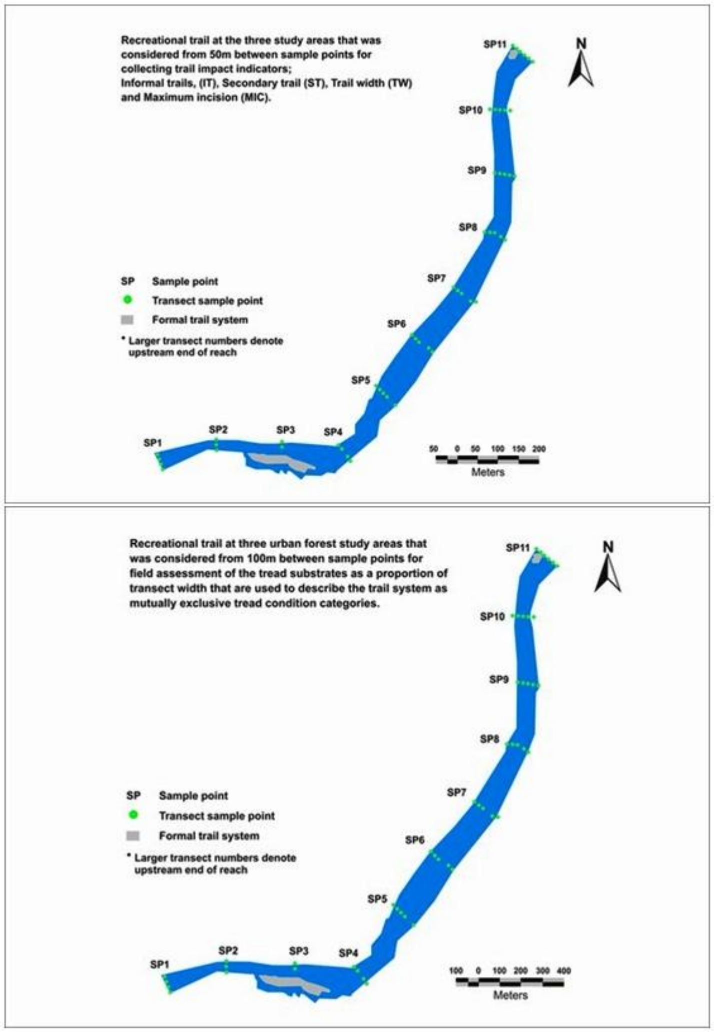

Figure 7 - Graphical illustration of point sampling with condition class assessment methodology used for collecting trail impacts (by Phanuel Gae)

Precisely, along the trail segments common impacts were documented by surveying the overall trail using biophysical trail indicators. These indicators and technique used have been described in greater detail below and represent the biophysical impacts assessed at the three urban forests selected trails.

2.2.1 Trail width

Trail with (TW) is define as the length of the transect width describes pronounce changes in outer-boundary vegetation cover from use level (Aust and Marion, 2005).

Thus, at the endpoints of the trail tread transect, human impact was recognized, identified, and described as the most pronounced outer-boundary disturbances resulting from human alteration in ground vegetation height; trail maintenance activities such as vegetation clearing is overlooked. Clearly seen boundaries were categorized as trampled and untrampled depending on the changes in ground vegetation height. Also, the vegetation covers along the trail outer-boundary that show intact and pulverized or when vegetation cover decrease or completely missing was clearly detail. The main goal is to document the trail tread that experienced the greatest amount of human impact as shown in (Figure 8). All secondary treads were included as recognized by the tread boundary. Two metal stakes were temporary located at the trail outer-boundary points and measurements were taken at the two transect point, thus the tread width to the nearest centimeters.

Note: The line was moved forward in one foot increment if obstructed by root or rock and all other obstructing materials like litter are removed for a clear measurement location.

Figure 8 - Examples of trail width with outer-boundary that experience different levels of human impacts resulting alteration in ground vegetation height **(Photographs: Gade, 2015)**

2.2.2 Maximum incision (current tread)

Maximum incision (MI) defines soil loss on surface of trail by displacement of soil from wind and water to the trail side. This occurs as a result of repetitive walking, hiking or hooves of horses, which disentangle compacted soil particles resulting to erosion on trail. The main target was to record a measurement that reflects the maximum amount of soil loss by soil erosion and/or compaction along the transect within the tread boundaries. Therefore, at each trail sample point, a nylon string was stretched out and fastened between two metal pegs that can describe the tread boundaries. The string was well secured by two metal stakes fixed perpendicular to the trail tread and maximum incision (MIC) was identified and measured from the string to the deepest portion of the trail tread to the nearest centimeters/meters (Figure 9). A recurrent problem that affects both the accuracy and precision (reliability) of trail incision measurement are differing determinations of the appropriate upper datum to obtain the actual measurement.

Note: the surface of the tread's substrate was measured excluding the tops of rocks or the surface of mud puddles.

Figure 6 - An illustration of how maximum incision was recorded using a nylon string fastened between two metal pegs that can describe the tread boundaries (Photographs: Gade, 2015)

2.2.3 Informal trails

Informal trails (IT) are unauthorized trails created and accessed by trail users to provide experiences and desires to reach locations not accessible by formal trails. All visitors' created paths or tracks that developed from the main trail were counted and recorded individually to provide point sampling data for a number of trail condition indicators. This also provided quantitative data for number of user created trails that can be used by trail managers for point sampling analysis. The lineal extent of visitor created paths were not assessed and mapped because of much larger trail system encountered in Wild Šárka. Though, it might provide interesting and useful data in identifying potentially susceptible areas and their length, which can later be used by trail managers.

2.2.4 Secondary trails/treads

Secondary trails/treads (ST) are partially developing eroded braided trails parallel to the main tread. These ST were counted and tallied at each sample points irrespective of their distances. The main treads were not tallied in this objective, because the principle goal was to understand the carrying capacity of the main trail that can develop into network of braided or new unofficial trails as a result of extensive user traffic illustrated in Figure 10.

Figure 10 - Network of braided trail that parallel the main trail at the Wild Šárka study area (Photographs: Gade, 2015).

2.2.5 Estimating tread condition characteristics

The main objective was to provide trail managers with the most common properties or conditions that occur frequently on the trail tread, so that the location and the extent of damage can obviously be identified. At each sample point (100m) within the trail tread transect width, the direct (linear) length of any of the tread surface categories (<u>litter,</u>

vegetation cover, exposed rock, exposed root, length of imported gravel, running water on trail together with mud, wood, and other materials) were subjectively observed and estimated to the nearest 5-10% in order that all estimates were summed to 100%. For example, a transect might have 25% organic litter, 40% bare soil, 10% rock, and 25% vegetation cover. Note that the vegetation cover could be 10% on one side of the trail and 15% on the other side, which together is 25%.It is possible to have a trail tread which could appear to be 100% rock or 100% soil. However, exposed roots observed below 5% were ignored.

Note: The description of the thresholds of the tread condition characteristics is outlined in appendix?

2.2.6 Testing the potential trails impacts indicators for analysis

Data from only the three potential trail impacts indicators were entered into an Excel spreadsheet and imported to the SPSS statistical 20 package for analyses. One-way ANOVA and Turkey post hoc analysis were conducted. The selected trails from the three urban forests were compared based on their impact indicators to determine the site which has experienced greater impact from users. The three types of trail impact indicators were tested for the analysis because they provide general condition of the trail resources. Secondary trails were rare in the entire study sites; hence the summary of their data in Table 9 only provides information needed for trail maintenance work.

This was followed by conducting the test of coefficient of variation for all trails to eventually determine the relative variability of each trail, thus trails that have the high tendency to face degradation or simply, the expected behavior of the trails if there are less intensive management operations.

In this case, coefficient of variation was conducted for each of the trails studied using the resultant means and the standard deviation for the three indicators , using the following formula and results are presented in Table 7: Coefficient of variation (CV %) $=100\times\frac{std\ dev}{mean}$ and the results.

Data from trail substrates (vegetation cover, organic litter, exposed soil and muddy soil together with water on trail, gravel, rocks and also wood) were input into an Excel spread sheet and their mean trail substrate cover as a proportion of transect width was determined.

3. Results

3.1 Impacts of recreation trail use on the urban forest

The results of the primary data are presented in Appendix iv for trail impact indicators that describe trail conditions (IT, ST, TW, and MIC). The primary data from trail substrates (vegetation cover, organic litter, exposed soil and muddy soil together with water on trail, rock, gravel, and roots and other categories) are presented in Appendix v.

The results obtained from the test of analysis of variance (ANOVA) for the three study sites trails using their potential trail impact indicators to evidence the general condition of the studied trails are shown in Table 6. This is also followed by graphical presentation of the field assessments of trail substrates in Figures 10, 11 and 12.

More in-depth presentations of the results are discussed under each impact indicators with respect to specific study site. The discussion is also accompanied with illustrations from the survey to provide additional insight into the conditions of all the trails assessed. This will also help to recognize factors that forest managers might employ to spur sustainable trail use alongside and reducing as much as possible existent trail impacts. Finally, the general assessment of trail condition is presented in Appendix 3 using parameters from some impact indicators; trail width, maximum incision and informal trails regarding to the trail degradation level model presented in Appendix 2.

Table 5 - Descriptive statistics for the potential trail impact indicators (MIC, TW, IT) for the three study sites. The subscript defines the mean sharing of each trails indicator: (a) = Low impact indicator due low mean average; (b) = High impact indicator due high mean average

Trail indicators	Study site	Mean	Std. Deviation	Sample Points
MIC	Bohnické trails	0.48417[b]	0.847111	60
	Ďáblický trails	0.22525[a]	0.129965	59
	Wild Šárka trail	0.26729[a]	0.363535	236
	Total	0.29696	0.466351	355
TW	Bohnické trails	3.675[b]	0.4074	60
	Ďáblický trails	3.46746[a]	0.522958	59
	Wild Šárka trail	3.43148[a]	0.584054	236
	Total	3.47862	0.554038	355
IT	Bohnické trails	1.23333[a]	1.047461	60
	Ďáblický trails	2.18644[b]	1.525356	59
	Wild Šárka trail	1.72458[b]	1.303183	236
	Total	1.71831	1.329618	355

Table 6 - Analyses of variance (ANOVA) of potential trail impact indicators (MIC, TW and IT) for all study sites

Trail indicators		**Sum of squares**	**df**	**Mean square**	**F**	**Sign**
MIC	Between Group	2.614	2	1.307	6.186	0.002
	Within Group	74.375	352	0.211		
	Total	76.989	354			
TW	Between Group	2.846	2	1.423	6.186	0.009
	Within Group	105.818	352	0.301		
	Total	108.663	354			
IT	Between Group	27.051	2	13.526	7.951	0.001
	Within Group	598.78	352	1.701		
	Total	625.831	354			

Table 7 - Descriptive statistic for TW, MIC and IT for all study sites

TW	**N**	**MEAN**	**SD**	**CV'**
BBT	24	3.7375^{b}	0.090852	2.431
BNT	36	3.63333^{b}	0.063496	1.748
DGT	27	3.52222^{ab}	0.083604	2.374
DYT	32	3.42125^{ab}	0.104371	3.051
WSRT	161	3.54472^{b}	0.052068	1.469
WSYT	75	3.1884a	0.026265	0.824
Total	355	347.862	0.029405	
MIC				
BBT	24	0.50792^{a}	0.195398	38.4702
BNT	36	0.46833^{c}	0.129835	27.7221
DGT	27	0.28704^{b}	0.010347	36.047
DYT	32	0.17313^{a}	0.026837	15.501
WSRT	161	0.36621^{b}	0.030901	8.438
WSYT	75	0.05493^{a}	0.016453	29.952
Total	355	0.29696	0.024751	
IT				
BBT	24	141.667^{ab}	0.207789	0.147
BNT	36	111.111^{a}	0.177182	0.159
DGT	27	225.926^{b}	0.285413	0.126
DYT	32	212.500^{b}	0.279508	0.131
WSRT	161	168.944^{b}	0.105086	0.062
WSYT	75	180.000^{b}	0.14332	0.071
Total	355	172	0.070569	

The subscripts define the mean sharing of each trail: (a) = Lower impact indicator due lower mean average; (b) = High impact indicators due to high average; (c) = Lower impact indicators due to lower mean averages

Table 8 - Analysis of variance (ANOVA) for trail impact indicators within the study sites

IT	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29,285	5	5.857	3.427	0.005
Within Groups	596,546	349	1.709		
Total	625,831	354			

*Only Informal trails show significant impact when potential trail impact indicators within the urban forest study areas were tested.

Table 9 - Point Sampling quantitative data for informal trails and secondary trails at the study sites

Study areas	IT	ST	Sample Points
Bohnické Trails	74	7	60
Ďáblický forest Trails	129	9	59
Wild Šárka Trails	407	17	236
Total	601	33	355

3.2 Results for the trail substrate means

3.2.1 Bohnické a Draháňské valley trail substrate means

Field assessment of the tread substrates as a proportion of transects width which is used to describe the trail system as mutually exclusive tread condition categories. The main tread substrate of Bohnické a Draháňské valley trails is man-made materials including; asphalt, constructed boardwalk, together with water bars, and concrete structures (30%), followed by organic litter (24%) and naturally occurring rock surface contributes 23% and 6% vegetation (Figure 11). The other categories (4%) includes horse dung occupying transect width of the trail, (1%) human placed gravel, (2%) exposed root and (1%) wood. Water and mud categories were also assessed but rarely encountered mainly due to the time of year.

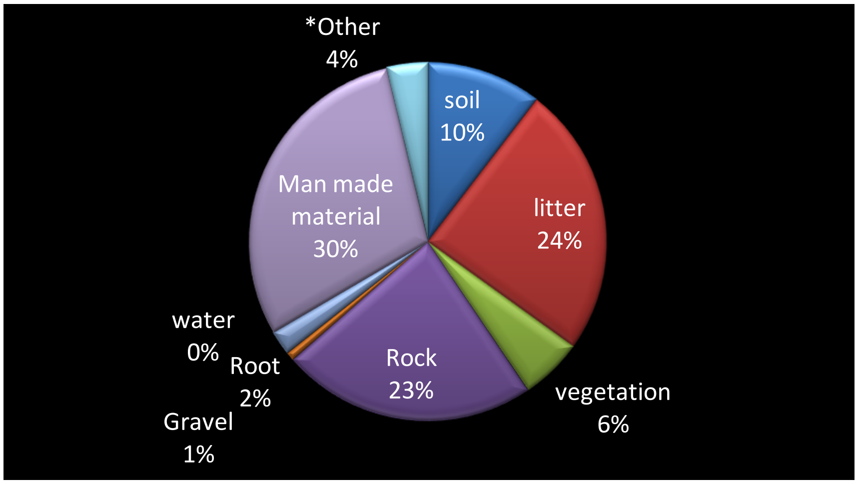

Figure 11 - Mean trail substrates cover as a proportion of transect (tread) width at Bohnické a Draháňské Valley trails.

3.2.2 Ďáblický forest trail substrate means

The main tread substrate of Ďáblický forest trail is gravel (51%), followed by man-made materials such as: asphalt, constructed boardwalk, and concrete structures (19%) and (15%) organic litter and naturally occurring rock surface contributes 8% and 4% vegetation (Figure 12). The other categories were also examined of which (3.0%) include exposed soil, (0.0%) made up of exposed root (0.0%) occupying transects width of the trail. The water category was also assessed and (0.0%) represents standing water or water on trail, (0.0%) mud, however due to the time of year these were rarely encountered.

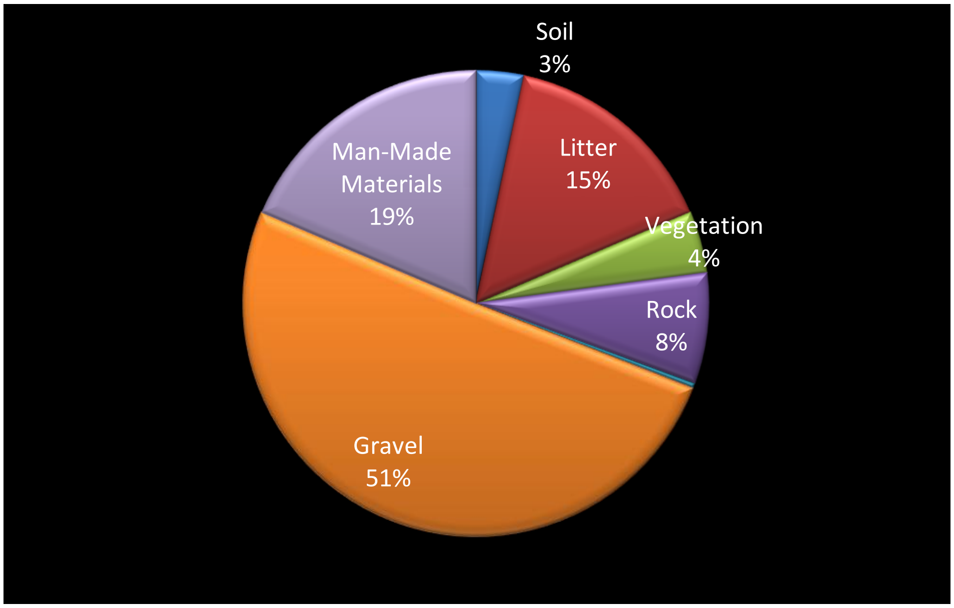

Figure 72 - Mean trail substrates cover as a proportion of transects (tread) width for Ďáblický forest trails

3.2.3 Wild Šárka tread substrates means

The main tread substrate of Wild Šárka trails is comprised of man-made materials including; asphalt, constructed boardwalk, and concrete structures (38%), followed by organic litter (19%) and naturally occurring rock surface contributes 15% and 14% vegetation (see Figure 13). The other categories examined; (7%) include human placed gravel, (1%) exposed root and (1%) also wood occupying transect width of the trail. However, due to the time of year these were rarely encountered.

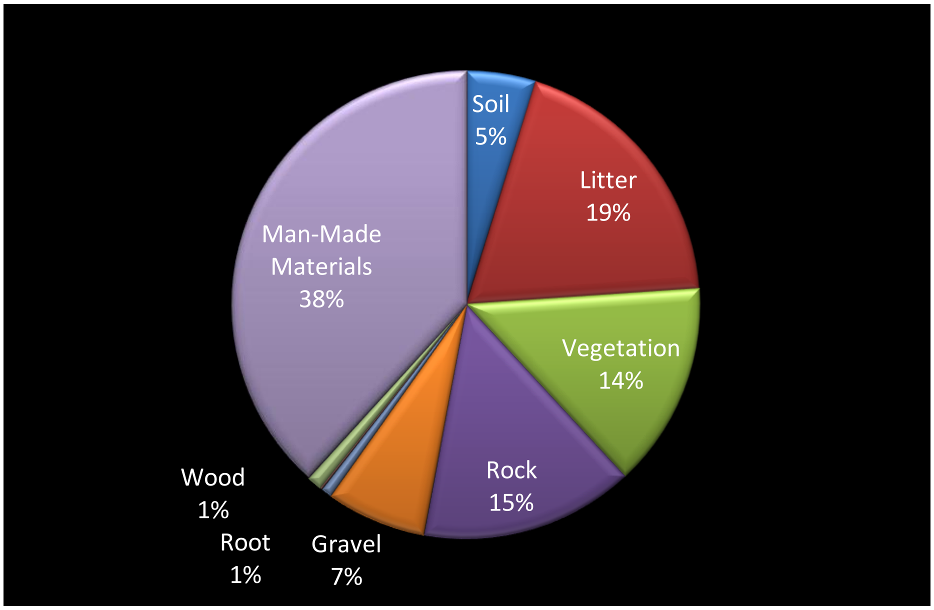

Figure 13 - Mean trail substrate cover as a proportion of transect (tread) width for Wild Šárka trails

4. Discussion

Sequel to the analysis, the potential trail impact indicators showed that there was statistically significant impact of recreational trail use in all the three urban forests, thus impacts of recreational trail use were produced on the indicators. Therefore, potential trail impacts indicators of the three urban forests Urban forests were statistically significant for the results of MIC ($p < 0.002$), TW ($p < 0.009$) and IT ($p < 0.001$) as presented in Table 6 after testing the potential trail indicators for the study sites.

This is confirmed by conducting the test that compares every trail within the urban forest using the analysis of variance but was not statistically appropriate. Samples for TW and MIC were strange and inconsistent (Appendix iv), and thus, only IT were compared. Secondary trails occurred on some of the trails but most cases rare, so only the three potential trail impacts indicators were tested. Quantitative data about their occurrences are available in appendix 5 for future trail monitoring.

The descriptive statistics obtained from the entire potential trail indicators revealed that the three urban forests trails experience significant impact from users. This is also confirmed by results obtained for comparing IT within in the study areas, which showed significant impact ($p < 0.005$). The discussions of the results are presented on each section related to the impact indicators for the study areas.

4.1 Trail width for study areas trails

Trail widening appears to be a problem affecting all the three study areas trails. This is well pronounced on all the trails and proved statistically significant at $p < 0.009$ when the results from the observation were tested. In regards to observation and measurement of TW for the three urban forests, results ranged from 2 to 4 meters (Appendix v) with different mean averages from the statistical analysis in (Table 5). This suggests that extensive trail expansion is a common impact as a consequence of insensitive. This was encountered during trail observation at three urban forests and proved statistically significant when the results were tested. According to the descriptive analysis of the mean averages of TW for all the three urban forests trails in table 7, the figures are closely related; Bohnické trail (3.73750^{b}), Ďáblice trail (3.46746^{b}) and Wild Šárka (3.43148^{b}). The closely related mean averages obtained from the test probably suggest an indication of a close relationship of level of trail widening from users in all the three urban forests study areas.

Though, their means show closeness, which suggests that all the study trails experience the same consistent level of impact of trail expansion, there is a clear indication of highest trail widening in Bohnické trails. This is probably due to various conditions surrounding the usage of that urban forest trails. Some of these conditions noted at this study site are scenic attractions including; the presence of the botanical garden and it closeness to the Prague Zoo, which ultimately makes it very attractive and therefore encourage high volume of trail users and might probably cause user traffic. These conditions might probably contribute to the high mean averages obtained from the trail width.

These factors directly determines it high use level and influence its trail widening behavior. This agrees with the findings of Wimpey and Marion (2010), who discovered six general behaviors that contribute to trail widening such as; i) overtaking other trail users; ii) side-by-side trail walk; iii) avoidance of tread problems for instance; muddiness, erosion exposed rock or root with roughness experiences and sometimes avoidance of standing water on trails (Figure 16c); iv) poor nature of trails that prevent users to travel on trails; v) meandering on trail related to selecting easiest truck when traversing on trail located along a steep slope; and vi) when users try to catch attractions closer to the trail they eventually diverge and trample on the trail side Figure 14.

Figure 14 An urban forest paved trail without constructed trail side-hill, which result to outer-boundary disturbances as users venture off the trails. (Photographs by Phanuel Gade)

Figure 15 - Example of trail with flatter side-slope at Ďáblický forest which offers low resistant trail widening as well as little resistant to prevent or obstruct the drainage of water from incised trail treads. This can also encourage proliferation of unauthorized trails because of open meadows at trail side.

Following the observation at Ďáblický forest the trails are ascended and located on low slope and this is highly susceptible to trail widening. Therefore, related studies have documented that such trails will have greater velocity and erosive of surface runoff (Aust et al., 2005). This is because topography influences trail degradation and has positive relationship between trail slopes and soil loss (Weaver and Dale, 1978). The trails have flatter side-slope and less dense trail side meadows and open meadows (Figure 15). This offers low resistant to trail widening as well as little resistant to prevent or obstruct the drainage of water from incised trail treads (Aust et al., 2005).

Also, as a result of low slope nature of the trails in Ďáblický forest, it can easily attract water and becomes highly susceptible to muddiness, because trails that traverse poorly drained soils are liable to muddiness. Finally, it can result to extensive trail widening as users seek to avoid tread problems and rather walk on the side trail. Realistically, this behavior becomes offensive and disrupts outdoor recreational settings.

Figure 16 - Examples of tread problem encountered on the trails in study areas; the pictures describe; (A) presences of horse manure on the trail tread. (B) Erosion exposed rocks on trail (C) erosion exposed roots on the trail (C) standing water on trail, which was not encountered again during data collection due to the season of the year. Avoidance of such condition leads to trail expansion. (Photographs by Phanuel Gade)

At Wild Šárka this situation is similar at the lower or flat ground of the trail system, yet in the middle of woods trails closely follow the land contour and have a high slope alignment angle from personal evaluation and critical judgment. Such locations of the trails have side-hills with steeper side-slopes which are naturally occurring or otherwise constructed side-hill trails (Figure 17). This condition facilitates tread drainage, minimizes the most common and significant trail degradation problems such as: tread erosion, muddiness, widening, and secondary treads (Agate 1996, Birchard and Proudman, 2000). The side-slope trails which follow the contour have developed a parallel berm of soil along their lower edge but usually this can be disturbed by drainage dip construction to allow water to drain off trail treads (Birchard and Proudman,2000; Hesselbarth and Vachowski, 2000). This condition could eventually reduce widening of trails (Figure 18).

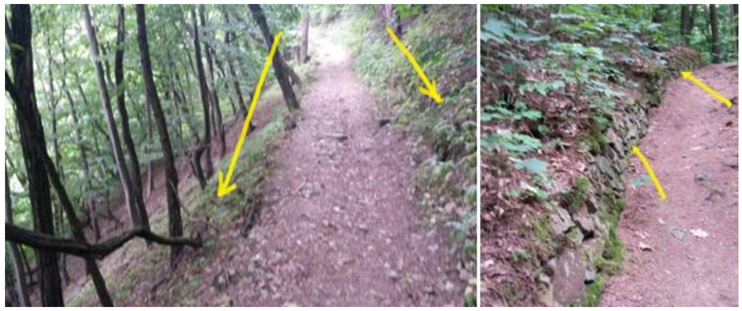

Figure 17 - Pictures of trail illustration from Wild Šárka urban forest with arrows showing side-hills with steeper side-slopes (left) and naturally occurring constructed side-hill trail which facilitate tread drainage and prevent proliferation of unauthorized trail. (Photographs by Phanuel Gade)

Figure 8 - The side-slope trails have developed a parallel berm of soil along their lower edge but usually this can be disturbed dip construction to allow water to drain off trail treads. (Photographs by Phanuel Gade)

4.2 Maximum incision for all study areas trails

Based on the statistical analysis for test of MIC at each sample point for the three urban forests (p-value 0.002) (Table 6). This suggests consistent soil loss on trails in all the three urban forests and it is a sign of degradation. This result corresponds with other related studies which documented MIC as the most significant ecological impact indicator of trails (Wimpey and Marion, 2011). The analysis reveals rapid removal of loose and unconsolidated soil particles from trail tread at Bohnické a Draháňské Valley as it records higher mean value of 0.48417^{b} compared to low mean values obtained for Ďáblický Forest (0.22525^{a}) and Wild Šárka (0.26729^{a}). The high incision obtained for Bohnické a Draháňské Valley trails is directly related to erosion effect and is an evidence of severely damage trail and could probably result to severely damage, which may negatively affect the sustainability of the purpose of the urban forest. This condition is quite clear with Bohnické a Draháňské Valley trails and corresponds with other similar related studies that incision is highest on un-surfaced trails tread, which experience high use.

It is important to know that the higher value of the MIC obtained for Bohnické a Draháňské Valley during the analysis of the impacts between the three urban forests termed to the prevailing likely contributors of erosion on un-surfaced trails; Bohnické a Draháňské údolí urban forest is very close to the botanical garden and Prague Zoo. This situation makes the urban forest more attractive and obviously accommodates higher volume of users on trail. Consequently, it is an implication of trail user traffic. As the trail experience high volume of users soil particles are gradually detached by human pressure, likely slippage of feet and hooves of their dogs or horses, thus making particles loose and unconsolidated. This persistent condition has a clear influence on the high mean value obtained for the soil loss on trail.

The analysis shows that Ďáblický forest trail and Wild Šárka have relatively similar and incision. This can be observed from their means when comparing the three forests trail indicators. 0.22525^{a} and 0.26729^{a}, respectively. These two urban forests have the same level of impact from users resulting to the consistent soil loss/incision on the trail tread. This result corresponds with the result obtained from trail substrates which recorded high proportion of human placed gravel of 51% on Ďáblický forest trail system and 7% for Wild Šárka trail system. The two urban forests exhibit evidence of some level of managerial actions such as; human placed gravel on trail; which limit occurrences of erosion and the presence of man-made materials; such as water bars (Figure 19) that can possibly route run off away from the trail tread and reconstruction of some of degraded portion of the trail segments into asphalt (Figure 20 i). Apparently, the occurrences of relative low mean values of incision on the trail tread obtained for both urban forests signifies responsive managerial action to reduce soil erosion on trail.

Figure 19- Example of constructed water bar on trail segments in Ďáblický háj and Wild Šárka urban forest, which can reduce erosion on trail by routing run off away from trail

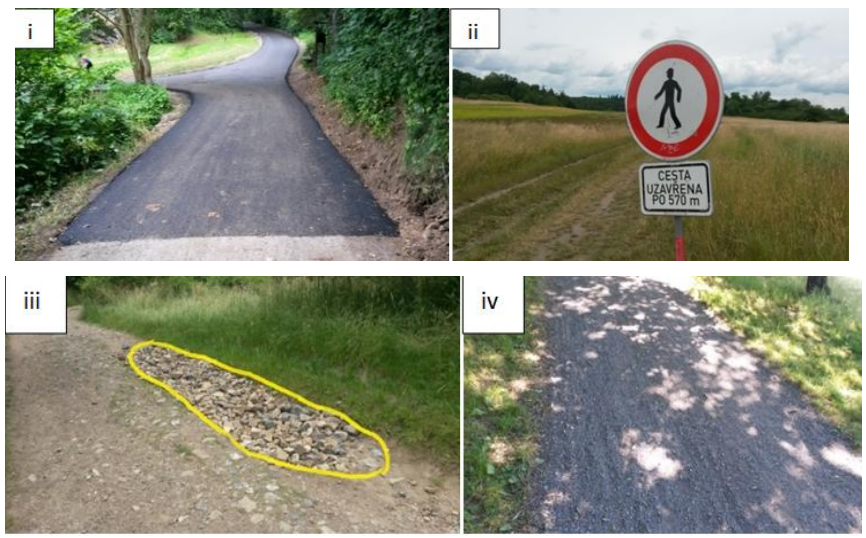

Figure 20 - Examples of some managerial activities to minimize trail degradation in the study areas; (i) reconstruction of some of degraded portion of the trail segments into asphalt (ii) Segment of the trail closed at Wild Šárka probably to allow maintenance work to be carried out (iii) stones placed to cover severely incised segment of trail at Wild Šárka (iv) Gravel placed on loose unconsolidated on the trail tread to prevent erosion. (Photographs by Phanuel Gade)

However, from the descriptive analysis it shows that the BBT has relatively higher mean value of loose soil on trail, thus the mean maximum incision recorded was 0.50792[a] which is a little higher than the mean obtained for the BNT (0.46833[c]) within the same forest. Comparatively, the indication of depth of incision is conveniently understood on the two trails within Bohnické a Draháňské Valley and it is more obvious than Ďáblický Fores and Wild Šárka trails. Specifically the result produced (0.28704[b]) for DGT and the DYT (0.17313[a]) are quite similar to WSRT (0.36621[b]) and rapid decrease of mean value was observed in WSYT (0.05493[a]).

Though, there is evidence to conceptualize the differences of soil loss that exist within six studied trails, it is statistically insignificance to accept the level of soil loss within the six trails, because the samples fail to fulfill the assumption to use the test of analysis of variance for testing individual trails within the urban forest.

On the other hand, BBT exhibited 4% of horse manure on its trail tread (Figure 11) and it is crucial to note that horses are the major causes of the most ecological trail impacts. Liddle, 1997 documented that horses exert ground pressure of about 18 Ibs/in^2 more than humans. Horses destroy vegetation and once the understory vegetation (plant life growing below forest canopy) is damaged the trail is prone to become loose and unconsolidated resulting to severe erosion. More so, manure on the trail creates both ecological and social problems. Manure can contain seeds of exotic plants, which can certainly cause dynamics in the urban forest and this will have direct effect on the aesthetic and the ecological composition of the forest (St John-Sweeting and Morris, 1991).

In addition, BNT is located on coarse-textured soil which has obvious resistant to erosion, yet the result for tread substrates characteristics shows that there is absence of water bar on both the blue and the natural trail. For that matter, the trail surface cannot direct storm water runoff away from the trail tread. This impact has considerable effect on the high maximum incision determined from the test between the three urban forest trail indicators. Therefore, soil loss on trail tread result to inability direct run off, so large volume of loose unconsolidated soils are carried during runoff and consequently incising the trail.

4.3 Informal trails in all study areas

Proliferations of unauthorized/informal trails were pronounced and consistent in all the three urban forests. From the result illustrated in Table 9, Bohnické a Draháňské valley recorded a total number of 74 informal trails traversed two formal trails, thus the blue trail and the natural trail at 60 sample points with a mean value of 1.233333[a] making it the lowest of observation. Ďáblický valley showed 129 informal trails development at 59 sample points and evidenced highest mean value of 2.18644[b]. Correspondently, Wild Šárka showed total number of 407 informal trails proliferation at 236 sample points and exhibited a 1.72458[b] mean value from the test. This indicates similar rate of proliferation of informal trails at both urban forests but again it statistically deviated at (1.303183) from the results of Ďáblický forest trails comparatively (Table 5). Statistically, the IT were highest at Ďáblický forest as predicted probably due to its proximity to Ladvi, and other nearby communities, which serve as shortcut routes to trail users to access the urban forest from their adjacent communities and roads. Furthermore, there is absence of trail side-hill (Figure 15) and trails are located on flat terrain with relatively shallow slopes. These are likely contributors to the proliferation of unauthorized trails because trail users do not face any obstacle to the adjacent vegetation.

In Bohnické a Draháňské valley, even though it showed decrease informal trail development, the number of counts proved statistically significant from the analysis of variance for all the three urban forests (p – value 0.001) (Table 6). The implication is that visitors are strongly influenced by the tread condition such as the horse manure observed on the trail (Figure 11) and (Figure 16A) such conditions on trails divert movement of trail users, so an attempt to pick the easiest route results to malicious damage to the vegetation (Marion and Wimpey, 2011).

This condition can also create forest patches and cause habitat fragmentation which will reduce total area of habitat, creating subpopulation of species and at the same time isolating that subpopulation from one another. Eventually, these human activities disrupt individual and population behavior and prevent exchange of gene between populations

(Hanski et al, 1995). On the other hand, the lowest result obtained as predicted appeared to be the presence of trail side boundary on the formal trails of Bohnické a Draháňské valley. This considerably discourages trail users from venturing into the adjacent vegetation.

In Wild Šárka, some portion of the formal trail segments pass through cliffs and as well located on steeper side slopes. This situation probably reduced proliferation IT from users, which corresponded with the statistical result obtained that deviated from the result from Ďáblický forest trails. The implication is that trails with steeper side slope tend to confine users to the trails (Figure 27). Meanwhile, some of the IT monitored or traced led to cut switchbacks such as rocks and down trees but faint.

4.4 Secondary trails

The occurrences of trails that parallel the main/popularly used trails were not statistically studied. These trails occurred on some of the trails but most cases rare and should not be confused with outer-boundary disturbances of trail as shown in Figure 21.

Their occurrence need further study in order to fully comprehend why trail users cause such impact, because it appears to occur in absence of tread condition problems such as; muddiness, horse manure and crowding. Data is available in Appendix v illustrating these occurrences. The data will serve as a protocol for monitoring and future studies about their existence on trails.

Figure 21 - Example of braided network of trails or secondary trails development at the study areas. (Photograps by Phanuel Gade)

4.5 Relative variability of all trails in the study areas

The risk-return trade-off for all the trails has been determined and the expected behavior of the indicators that would probably expose the trails to high risk of degradation in future has been analyzed. The analysis (Table 7) revealed that there is a lower ratio of standard deviation to mean return, thus the coefficient of variation (CV) evidenced less than 5% for TW and IT in all the all the three urban forest study areas. The implication is that there is expected lower risk of trail widening and proliferation of informal trails.

Contrary to this, the analysis again revealed relatively high CV for the most ecologically significant trail impact, (MIC) as documented by (Wimpey and Marion, 201), thus all the trails except Ďáblický forest green trail have a higher ratio of standard deviation to mean return for the MIC. Therefore, all the trails have high tendency to soil loss which would probably result to erosion development, hence trail degradation would be pronounced.

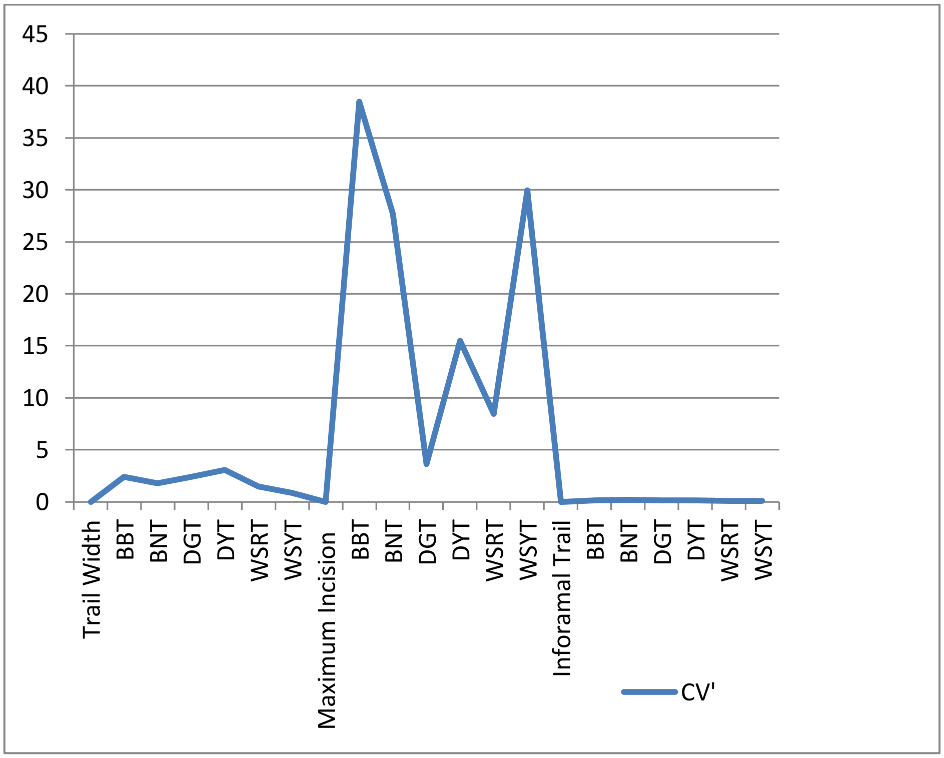

Figure 22 - The calculated relative Variability for all study areas trails (expected behavior of the indicators that would probably expose the trails and the urban to high risk of degradation).

The lowest CV' for MIC that occurred for Ďáblický forest green trail at (3.6047241) suggesting a lower risk of soil loss. Apparently, Ďáblický forest green trail has the similar tread condition characteristics as the yellow trails, because of some managerial operations (see Appendix v) but the exact reason for such behavior evidenced by Ďáblický forest green trail alone in the result is not yet known. The benefit of the CV' in this study is the ability to monitor all trails with intensive management plans in order to receive a good performance of the urban forests to meet both ecological and social demands. Therefore, in investing world there is a need to determine what happens to the trails when there are less intensive management strategies.

Clearly, the CV' for informal trails and trail width across all the three study sites occurred below 5% (Figure 20). This is an expected result of good performance probably due to some managerial actions as indicated, which influenced the result for the risk-return trade-off for all the trails. In this sense, all the urban forests trails studied have the tendency to experience minimum impact on vegetation and species habitat that might result from unauthorized development of trails from the formal trail system and extensive widening of trails. However, this is dependent on the least possible managerial actions.

On the other hand, the relatively high CV' exhibited by the most ecologically significant trail impact indicators (MIC) for the Bohnické a Draháňské valley blue trail is an evidence of expected high trail degradation probably due to presence of horses on that particular trail. This is true because horses have documented a significant increase for high erosion susceptibility (Hammit and Cole, 1998). Evidently, unshod horses exert approximately a weight of 18 Ibs/in^2 ground pressure and 62 Ibs/n^2 for shod horses, 2.9 Ibs/n^2 noted for hiker in a boots (Liddle, 1997). Obviously, presence of horses on trails contributes to severe trail degradation, which accounts for major ecological impacts on pristine forest areas delineate for recreation.

Inconsistencies noticed were the difficulties to assess trail widening at some parts of the trails system. Notably, Wild Šárka, red trails because of wood and cliff nature, which appeared very steep, though adventurous. Therefore, data is unavailable for such instances.

Also data is unavailable for soil loss (MIC) on parts of paved trails since impacts mostly occur on unpaved trails but paved trails whose outer-boundary vegetation appeared disturbed were considered as shown in Figure 14. The details of these inconsistent data can be observed from the worksheet in Appendices 4 and 5. The column which recorded 0 indicated absence of data as result of natural factors such as wood trails, cliff nature of trails and sometimes meandering of trails along the slope.

5. Conclusion

Results revealed that the indicators MIC, TW, and IT experienced significant impact from users on the three urban forests studied. Therefore, there is a consistent soil loss, trail widening and proliferation of unauthorized trails in all the urban forest study areas.

This observation supports the fact that impacts from outdoor recreation are unavoidable even with very low levels of visitor traffic on urban forest trails. So, From the condition class assessment level for all the trails and with a critical reference to the threshold of the impact indicators of trail degradation level model in Appendix ii. All the studied trails in the three urban forests are not severely damaged, Dablice and Wild Šárka trails are quite stable while Bohnické a Draháňské trails revealed to be in high usage, hence moderately damaged. The result indicates that bad trail conditions are found on part of each trail but not a whole trail and is in relationship with some managerial factors evidenced by mutually exclusive tread condition categories assessment. Therefore, physical variables are related to the most severe trail conditions.

The findings from this study exhibit that trail conditions depends on intensity of combination of different related outdoor activities and local physical properties such as; spatial distribution of impacts and ecological sensitivity as documented by (Ólafsdóttir and Runnström, 2013) and supported by (Cole, 2004) who suggested that the most influencing factors of trail condition are intensity of use and particular area of impact. Thus the result provide interesting but crucial indication that trails that are also used by horses and trails without trail tread have the tendency to face high degradation if there is less intensive management plans to minimize the associated impacts. The three case study sites surveyed highlighted many of the popular urban forest recreational areas in Czech Republic and beyond. They serve as a typical example of impressive but sensitive resources attracting people to outdoor participation and nature tour hence impact to trail is susceptible.

For this reason result from the assessment provides evidence that recreational trail use is usually associated with impact such as; soil erosion, vegetation damage including understory vegetation, and habitat disruption. Thus unsuitable environmental outcomes that inevitably precede outdoor recreation and participation in natural areas may trigger subsequent degradation of the natural landscape and the urban forest ecosystem by impacting larger areas as supported by (Greipsson, 2012; Ólafsdóttir and Runnström, 2013). Emphasizing a country's fragile ecological balance, a relatively slight damage or impact to the vegetation cover and the landscape from outdoor recreation is enough to expose it to water erosion. This can easily result to severe land degradation which may damage the urban forest and decrease the value of outdoor recreation and the purpose of the urban forest. Clearly, outdoor recreation to natural areas has effect on the ecological components. For this reason, an environmental management plan is necessary to minimize any potential trail impacts once they have been identified.

Therefore, the methodology approach in this study would serve as a protocol for periodic assessment of the identified impacts, though would not be useful in identifying potential susceptible areas because its time consuming locating lineal extent of all IT. Furthermore, the methodology is also based on low-cost and easily applicable, but yet quite time consuming because whiles visual assessment was made for major trail impact indicators some potential impact indicator such as; TW, MIC demanded direct measurement from the temporally fixed sample points. As a result of this the methodology was not applicable to assess and map lineal extent of informal trials.

Finally, using the two methods have proven to be more effective and efficient as a methodology for conducting periodic assessment and monitoring of trail conditions. Therefore, the indicators of impacts to trail condition have become an important concern for the health of the urban forest. By contrast, point sampling produces a more accurate and exact measurement of trail attributes that occur frequently, such as the width of the trail and soil exposure. Thus, integrating condition-class with point-sampling is based on its prime advantage of convenience and easy interpretation of data. Hence, the variable data that occurred across specific sites can easily be presented.

6. Recommendations

What is clear is that urban forest managers need to minimize trail expansion, formation of new informal trail networks and manage existing trail networks to reduce the impact of recreational trail use on the urban forest.

Therefore, spatial data on local physical properties would be needed to improve a more reliable model of different factors influencing urban forest trails in Czech Republic and to understand the complexity that exist between different outdoor activities and factors influencing trail degradation. These spatial attributes include the location, arrangement, and lineal extent of ITs.

Also, there is need to determine carrying capacities for each of the urban forest if patterns of visitation are consistent with the ecological carrying capacities. This study will serve as a protocol for developing a general management plan alongside the chosen methodology of this study. However, a monitoring program can only identify and evaluate trends when data are compared between present and past assessments. On the contrary, it was noted that urban forest recreational trails challenges research does not attract necessary and much needed attention from the managers of the study areas. This is because the management showed no interest after several attempt to seek their view about how they perceive the impact development and outdoor reaction from trail users, and to determine if this is consistent with their management actions.

Clearly, this suggests that those urban forest trails are not given much needed attention in the study areas despite susceptible direct and indirect impact on the fragile ecosystem. All the assessed trails are increasing attracting more popular types of outdoor recreation, for instance mountain biking and mountain marathon racing. These two outdoor participation and others according to (Ólafsdóttir and Runnström, 2013) have extensive impact on trail and the environment. As such, management of trails require urgent attention and regular monitoring to document the changes in order understand the level at which impacts are acceptable to enhance long term benefit of outdoor recreation. Therefore, to improve and sustain the overall benefit of outdoor recreation in vulnerable ecosystem like Czech Republic there is a need to build holistic understanding of management and location of trail system in the urban forest.

The following measures or recommendations have been suggested based careful observation of the bio-physical properties of all the trails systems and their location in the three study areas and with reference to (Brown et al, 1997; Deluca et al, 1998).What is obvious to note is that urban forest managers need to minimize considerably the impact of recreational trail use on the urban forest. Therefore, trails should be located on soils with low erodibility, thus such trails should have coarse-textured with low organic matter and low soil moisture. These measures would reduce soil erosion that might result to occupancies of incision on trail (Figure 23).

Figure 23 - Example of coarse-textured and low organic matter with low soil moisture on trail tread that would probably reduce soil erosion that could result to incision. (Photograph by Phanuel Gade)

Trails should be designed to follow the contour and use water bars on trail to route runoff away from trail as illustrated in Figures 19, 24 and 27.

Figure 24 - Example of trail that follows contour at Wild Sarka Study area. This facilitates trail drainage and at the same time confines users to trail without diverging to the vegetation. (Photographs by Phanuel Gade)

Wet soils should be bridged whiles avoiding steep slopes, which also reduce soil erosion.

Trails can also be structured with constructed boardwalk which facilitates ecosystem protection by preventing trail users from venturing into dense vegetation, specifically understory vegetation. Constructed boardwalks provide a convenient access to through standing waters and deep organic soil or muddy spots (Figure 25).

Figure 25 - Examples of constructed boardwalks which can facilitate protection of urban forest understory vegetation and also provide easy access through standing waters or muddy spots (Manual and guide for trail design)

Trail surface materials such as much or crushed gravels should be used to minimize the rate of erosion. See photo illustration in (Figure 26)

Figure 26 - Example of crushed gravels that can be used minimizes the rate of erosion in degraded segments of trails. (Photographs by Phanuel Gade)

Also, trails should not have shallow side slopes, because shallow slopes allow for undesirable trail widening and proliferation of unauthorized trails. Therefore, trails should have steeper side slopes, which tend to confine users to the trail (Figure 27).

Finally, environmental educational program should be given to the general public especially the youth about how to behave responsibly in urban forests.

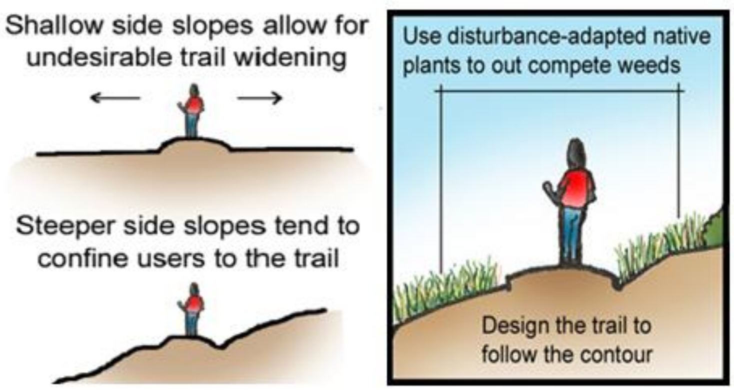

Figure 27 - Trail management strategies that reduce extensive widening of trails and minimizes user created routes; Trails should not be located on shallow slopes which turns to encourage trail traversing and confining users to trail discourage taking easiest routes that characterize unauthorized trails (Photograph extracted from conservation Buffers; USDA National Agroforestry Center).

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