EFFECTS OF LAND USE AND LAND COVER ON OCCURRENCE OF BARN OWL (*Tyto alba* Scopoli, 1769) IN KATHMANDU VALLEY, NEPAL

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RECOMMENDATIONS

This is to recommend that the thesis entitled **"Effects of Land Use and Land Cover on occurrence of Barn owl (*Tyto alba* Scopoli, 1769) in Kathmandu valley, Nepal"** has been carried out by Sabita Gurung for the partial fulfilment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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ABSTRACT

Barn owl is a flagship and an indicator species of healthy grassland, and closely associated with agricultural area. Study on its presence and abundance is very important in order to understand the state of the ecosystem. No study has been done on Barn owl in Nepal and the effects of Land Use and Land Cover (LULC) on its occurrence remain unknown. This study was designed to assess the effects of the LULC on the occurrence of Barn owl in Kathmandu valley from July till December 2014 with monitoring till February 2015. Post-earthquake scoping survey was conducted from mid May till July 2015. Sampling design resulted total 17 plots of 1.5 km radius and 68 sub-plots of 250 m radius. Survey was conducted within the plots at day time with intensive survey in sub-plots. Sub-plots with inconclusive evidence of occurrence were surveyed with both visual and aural survey aided with play-back recordings for an hour before and after sunset. LULC mapping was done on IKONOS image in ArcGIS. A total of 261.95 km of major roads, 187.68 km rivers and 216 temples were digitized. Plot-level mapping resulted 52% grass cover, 41% built-up, 6% tree cover and 1 % water body. Site-level LULC revealed total 4.86 km^2 of built-up, 7.62 km^2 of grass cover, 0.78 km^2 of tree cover and 0.08 km^2 of water body. Barn owl was recorded in 11 plots out of 17 plots. Barn owls occurred in 69 sites including 50 sites within the plots that constituted 54% Temporary Rest Site (TRS), 20% Active Roost Site (ARS), 14% Occupied Breeding Site (OBC), 8% site with death record and 2% with live Barn owl in captive stage. Majority of the sites (51%) used by Barn owl were buildings for both ARS and OBS. One-way ANOVA revealed that the occurrence of Barn owl was significantly affected by built-up level [$F(2,14)= 5.049$, $p<0.05$]. Occupancy modeling in program PRESENCE revealed tree cover had greater weight in determining occupancy at plot-level. Barn owl occupancy was highly positively correlated with temple (1.55 ± 1). Built-up has strong positive association with occupancy of Barn owl at both plot-level (1.25 ± 0.69) and sub-plot level (8.871 ± 5.177). The earthquake has negatively affected the potential sites of Barn owl. Rapid urbanization may result decrease in suitable cavities for Barn owls, affect breeding success and prey abundance which should be studied in detail to understand the pattern of occupancy, and attributes supportive for their survival in complex urban area like Kathmandu valley.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
AIC	Akaike's Information Criterion
ARS	Active Roost Site
GIS	Geographic Information System
GPS	Global Positioning System
IRR	Inner Ring Road
km	Kilometer
LULC	Land Use and Land Cover
m	Meter
OBS	Occupied Breeding Site
ORR	Outer Ring Road
PNS	Potential Nest Site
RS	Remote Sensing
TRS	Temporary Rest Sites
VDC	Village Development Committee

1. INTRODUCTION

1.1. Background

The habitat and land use pattern is dynamic and changes over time as a result of natural and cultural processes (Brandt et al. 2002). Variation in spatial pattern in habitat influences the distribution and abundance of species. Rapid growth of human population has catalyzed two major shifts in landscape: increased heterogeneity (Benton et al. 2003) and the loss of agricultural landscape due to urbanization (Theobald 2001).

Of all the live birds, Barn owl (*Tyto alba*) has been found to be associated closely with humans and their habitat (de Bruijn 1994, Shawyer 1994). The history of the relationship between man and Barn owls can be traced back at least two millennia (Sparks and Soper 1989). The species is considered as a flagship and an indicator of healthy grassland habitats (Solymár and McCracken 2002). Barn owl is well adapted to human modified habitats, inhabiting mainly open to semi-open landscapes including agricultural fields, pastureland, waste ground, open woodland, parkland and urban or suburban areas (Mikkola 1983, Cramp 1998). The degradation, loss and fragmentation of grassland and agricultural landscape have been negatively influencing Barn owl population (Colvin 1985, Taylor 1994). Thus the study on the presence and abundance of Barn owl is very important in order to understand the state of ecosystems in these landscapes.

Kathmandu valley, with its highest human dominance in the entire country of Nepal, possesses diverse landscape elements supporting various wildlife species. The unplanned urbanization and increasing population have caused the spatial pattern of urbanization to be highly dynamic resulting in various environmental problems (Rimal 2012). But no study has been done on effects of urbanization on wildlife and specifically the extent to which these changes impact Barn owl distribution remain unexplored. The study on the effect of Land Use and Land Cover (LULC) on Barn owl distribution examines how its pattern of occupancy across the landscape correlate with the composition of its habitats (Lindenmayer and Fischer 2006) and habitat loss is simplest to detect at a landscape scale (Fahrig 2003). Thus in the long run, the study on pattern and changes in distribution and abundance of Barn owl can serve as a measure of human impact (Burnham et al. 1994) on the landscapes of the valley which is extensively fragmented and continually dominated by anthropogenic activities.

1.2. Barn owl

1.2.1. Taxonomy

Within the order Strigiformes (owls), Barn owls are classified in the family Tytonidae (Ridgway 1914), which includes the Sooty owls, Grass owls, Bay owls, Masked owls, and typical Barn owls. Fourteen species of Barn owls are described in the genus *Tyto* (Bruce 1999) and its thirty-six subspecies are distributed throughout the world (Taylor 1994). Two subspecies of Barn owl exist on the Indian subcontinent viz. *Tyto alba stertens* (Hartert 1929) in Nepal, India, Pakistan, Bangladesh, Sri Lanka, Bhutan, Burma and *Tyto alba deroepstroffi* (Hume 1875), a rare subspecies restricted to Andaman Islands of the Indian Ocean (Bunn et al. 1982, Ali and Ripley 1983, Taylor 1994*)*.

1.2.2. Description

The Barn owl is a medium-sized owl; distinguished from other owl species by their large, distinctive heart-shaped facial area lacking ear tufts (Marti et al. 2005). Males and females superficially appear similar, though females (33-40 cm in length and 420-700 gm in weight) are larger than males (32-39 cm in length and 400-560 gm in weight) (Marti 1990, Marti et al. 2005). The upper parts of Barn owls are tawny-colored, marked with black, white and gray with white face and under wings (Marti et al. 2005). They vocalize infrequently and give fewer types of vocalizations outside of the nesting season (Walk et al. 2010). Their best- known call is a long, drawn-out scream, most commonly given by males in flight near the nest, and other sounds include snores, twitters, mobbing calls, bill-snapping and wing-clapping in flight (Bunn et al. 1982).

1.2.3. Adaptive features

The Barn owl is renowned for its ability to locate potential prey using sound alone even in total darkness (Payne 1971, Konishi 1973). It has highly sensitive hearing: ear openings are at different angles covered by a flexible ruff made up of short, densely webbed feathers, which frames the face, turning it into a dish-like reflector for sound (Meyer 2008). This gives it very directional hearing (Payne 1971, Coles and Guppy 1988, von Campenhausen and Wagner 2006) enabling it ability to pinpoint the source of sound from several metres away (Meyer 2008). Another important adaptation is its silent flight:

the wings have a velvety "pile" on the feather surface, and the leading edges of the wing feathers have a fine comb which deadens the sound of the wing beats (Feduccia 1999). This silent flight does not alert the prey and also aids hearing (Hoffman 1997).

1.2.4. Habit and Habitat

1.2.4.1. Foraging

Barn owl typically forages by flying low over grassland habitat with frequent "hovering intervals" (Rosenburg 1986) in moth-like cruising flights close to the ground and from low perches (Bunn et al. 1982). Hunting takes place mostly within a couple of hours after sunset and again within a couple of hours prior to sunrise (Matteson and Petersen 1988, Marti et al. 2005). It can fly as much as five to seven kilometre (km) away from its nest site to forage (Marti 1992).

1.2.4.2. Diet

The Barn owl specialises in hunting small mammals (Taylor 1994); mainly small rodents (Yom-Tov and Wool 1997, Lekunze et al. 2001), with a distinct preference for voles (Colvin and McLean 1986, Campbell et al. 1987, Marti 1988, Yom-Tov and Wool 1997) and house rats (Meyer 2008). It also preys on shrews, moles, various species of mice, and occasionally birds (Rudolph 1978, Colvin and McLean 1986), amphibians, reptiles and insects (Mikkola 1983, Cramp 1998).

1.2.4.3. Nesting and Roosting

The nest and roost sites of Barn owl are closely associated with agricultural lands (Andrusiak 1994). They nest/roost in natural tree cavities (Bachynski and Harris 2002), tall structures like buildings, caves and well shafts (Meyer 2008). Nest boxes and a great variety of man-made structures (Hegdal and Blaskiewicz 1984), abandoned or unused buildings (Campbell and Campbell 1983), windmills (Kemp 1987), temples (Neelanarayanan 2009, Santhanakrishnan et al. 2011, Ali and Santhanakrishnan 2012), historical buildings, church and castles (de Bruijn 1994) are usually preferred. The nest and roost sites are usually located in dark conditions (Campbell and Campbell 1983, Andrusiak 1994). No nesting material is gathered, but most females arrange pellets, the regurgitated undigested material, as a nesting material (Marti 1992).

1.2.4.4. Reproduction

The Barn owl is a monogamous species (Marti et al. 2005) and breeds at any time of the year (Tarboton and Erasmus 1998), usually in response to periods after rain when rodent numbers are highest (Harrison et al. 1997). They lay three to six eggs, laying an egg at every 2-3 days interval, and are incubated for 30-34 days (Martinez and Lopez 1999). During incubation, the female rarely leaves the nest and the male supplies her with food (Marti et al. 2005). Owlets usually fledge by 50 to 55 days, but they can remain in the nest up to 80 days, depending on the number of eggs and the time interval between hatching of the chicks (Trapp 2003). A Barn owl is able to breed at about 10 months of age (Kemp 1987).

1.2.5. Ecological role

Barn owls have important role in controlling rodents particularly field rats in the agro-ecosystem (Lenton 1980, Lee 1997, Meyer 2008). Historically, they have been considered an ally of farmers due to their voracious appetite for voles and mice, which are considered pests of many agricultural crops (Solymár and McCracken 2002). Despite their smaller size, a high metabolic rate allows Barn owl to eat up to one-fourth of their body weight each day (Marti et al. 2005). A typical family of two adult and four young Barn owls is estimated to consume about 1000 rodents during the 10-week period of the year (Colvin 1985) and caches surplus food in times of high prey densities and during the early nesting stages (Marti 1992). Thus, being at the apex of the food chain and excellent predators of rodents, they keep a check on these destructive mammals, reduce the likelihood of deadly plague (Ramachandran Nambiar 1996) and maintain a natural balance of ecosystem (Call 1978).

1.2.6. Distribution and status

1.2.6.1. Global

The Barn owl is a cosmopolitan nocturnal bird found in all continents (König et al. 1999), except from the Arctic, Antarctic regions, big parts of Asia and North America (Mikkola 1983, Cramp 1998). They are absent in most of Indonesia, some Pacific islands and from north part of Himalayas in Asia (Bruce 1999). They occur in open habitats in tropical and temperate zones and are absent in polar, alpine, or heavily forested areas (Walk et al. 2010). The density of Barn owl is highly variable across its range: locally abundant in some places and sparsely distributed over other large geographic regions (Walk et al. 2010).

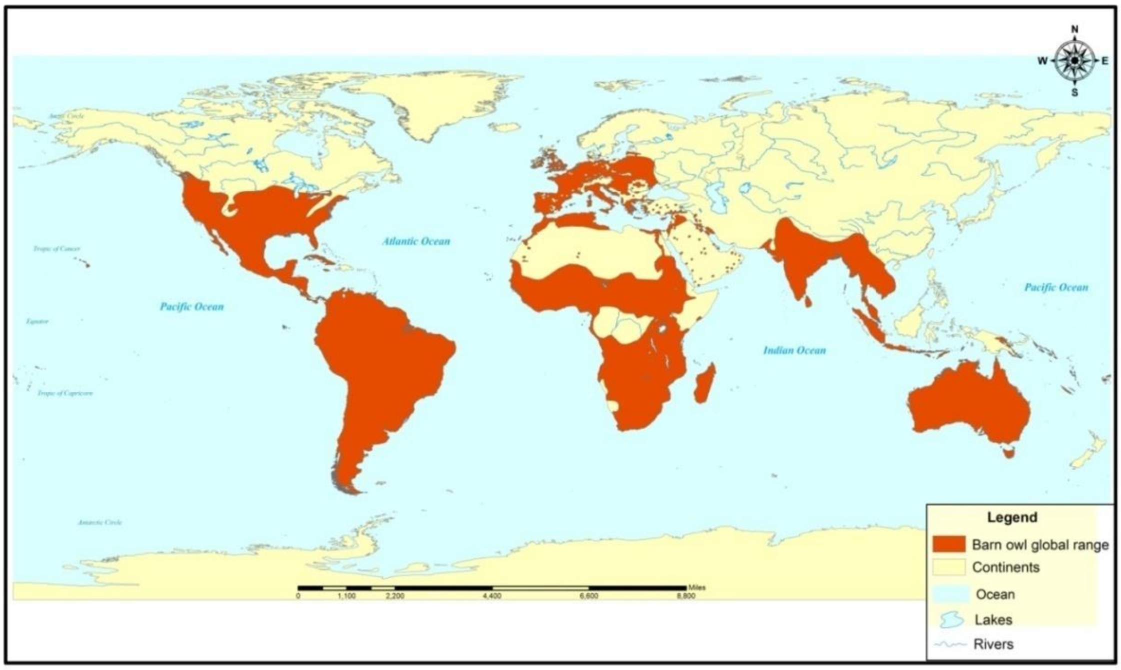

Figure 1. Global distribution of Barn owl (Source: Distribution map- IUCN 2014, World map- ESRI)

1.2.6.2. National

Barn owl was first time recorded in Nepal in the 19th century (Hodgson 1843); from the Kathmandu valley and central hills (Hodgson 1829). Outside the valley, it has been recorded mainly from the terai region i.e. from Chitwan district (Chaudhary 1999, Giri and Choudhary 2003), Banke district (Riessen 2010), Kapilvastu (Cox 2002, 2008), Rupandehi district (Chaudary 1998, Giri 2003) and Koshi (Baral 1993). Its occurrence in Nepal is described as 'occasional' (Fleming et al. 1976) and is considered a fairly common resident in urban areas of Kathmandu valley (Mallalieu 2008). It is a nationally threatened bird enlisted as Vulnerable in Nepal (BCN and DNPWC 2011).

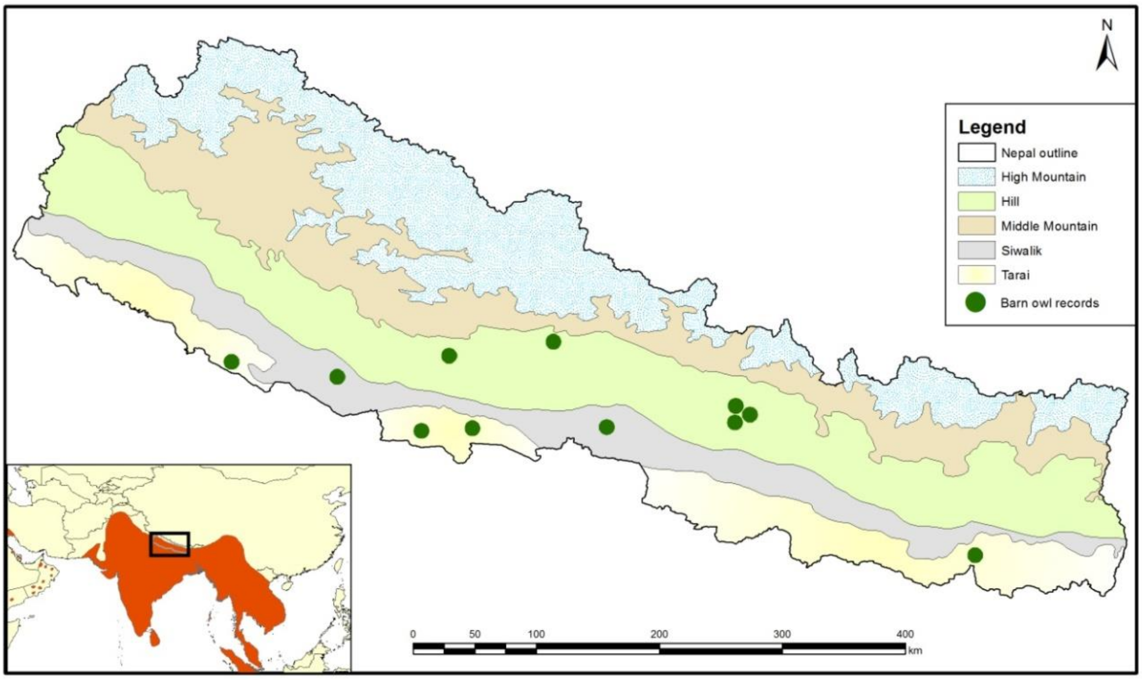

Figure 2. Distribution of Barn owl in Nepal (Source: Records from literatures and personal notes)

1.3. Rationale

Owls are group of birds which have never been studied scientifically in Nepal, and they are poorly recorded by multi-species surveys (Takats et al. 2001). The Barn owl is nationally threatened in Nepal (BCN and DNPWC 2011) mainly due to decline in population through poaching and trade in major cities including Kathmandu valley (Acharya and Ghimirey 2009) and loss of habitat (Gosai et al. 2012). Rapid transformation of the cultivated lands into urban areas is leading to an imbalance in the ratio of the LULC categories in the Kathmandu valley (Rimal 2012). The demolition of historical buildings, barns and huts, decrease in farmlands and expansion of concrete settlement may have effect on Barn owl habitat. But no study has been done on the Barn owl and also the effects of LULC pattern on its distribution in Nepal are unknown. Thus there is need of inventory on its distribution, habitat and ecological importance (Gosai et al. 2012).

Reliable baseline information about the species coupled with its interactions with other components of the ecosystem is extremely important to understand the ecosystem and initiate effective conservation measures. Without data on its presence, potential habitats and occupancy modeling based on the land features of the valley, it is difficult to devise management options to conserve the species. In this context, an inventory on the occurrence of Barn owl, its potential habitats, and effects of LULC features on occupancy of this species at multiple scales is very important in order to understand its present status and future sustainability within Kathmandu valley.

1.4. Objectives

General objective of the study was to evaluate effects of Land Use and Land Cover (LULC) on occurrence of Barn owl in Kathmandu valley, Nepal. The specific objectives were:

- To map LULC features in Kathmandu valley.
- To determine occurrence of Barn owl and its potential habitats in the valley, and
- To assess the effects of LULC on occurrence of Barn owl.

1.5. Limitations

- Due to lack of practical and applicable Barn owl research protocol for landscape features of the Kathmandu valley, the study needed extra time for re-designing research methods. This was a limitation at the initial phase of the research.

- The field survey was limited to a period of less than a year (July 2014 to February 2015). Also the scooping survey was mainly based on day time search of available potential structures mainly through interaction with locals and search of indirect signs. Owing to its difficult nature to sight and survey, and complex heterogeneous urban-rural feature of Kathmandu valley, the available time was not sufficient to identify all potential sites of Barn owl.

- The call count method for an hour before and after sunset i.e. 1700 to 1900 hours was found ineffective to get response from Barn owl. This could be due to disturbance by high traffic during that period and also could be due to the silent nature of Barn owl.

- The ongoing aftershocks, critical built-up structures at the verge of collapse at many areas, lack of safe equipments to approach the dangerous structures, and limited manpower and time were the constraints during the post-earthquake survey.

2. LITERATURE REVIEW

2.1. Land Use and Land Cover (LULC)- Study and Importance

Land use is "the total of arrangements, activities, and inputs that people undertake in a certain land type to produce, change or maintain it" and land cover is "the observed (bio) physical cover on the earth's surface" (Di Gregorio and Jansen 1998). The terms land use and land cover are often used interchangeably since the manner in which the land is used often has an associated type of cover (Anderson 1976). The landscapes are dynamic and change over time, and this contributes to the spatial patterning of habitats (Brandt et al. 2002). This spatial habitat pattern influences the distribution and abundance of species. Studies on the relation of the occupancy pattern of a species with the composition and configuration of habitat helps to understand the factors impacting its distribution (Lindenmayer and Fischer 2006).

Habitat loss is simplest to detect at a landscape scale, and habitat degradation due to human activities is known to be the primary cause in the decline in species worldwide (Fahrig 2003). The agricultural intensification and overall loss of habitat due to urbanization have resulted in decline in range and abundance of many birds associated with agricultural landscape (Fuller et al. 1995, Krebs et al. 1999, Brennan and Kuvlesky 2005, Donald et al. 2006). The rapid rate of human expansion and colonisation of new areas cause fragmentation and destruction of contiguous natural vegetation (Murcia 1995, Reino et al. 2009). Over the short term, fragmentation may reduce foraging efficiency, increase home range size (Redpath 1995) and restrict dispersal movements across fragmented landscapes due to increased mortality (Banks et al. 2004, Stow and Sannucks 2004). Such environmental impacts of LULC changes may not only impact the site of the change but may affect larger areas through complex pattern-process interactions (Gulinck et al. 1993). Renewed approaches in landscape ecology deal with such complex interactions (Zonneveld 1990). Recent advancements in GIS and Remote Sensing technologies provide powerful tool for mapping LULC, and these technologies in conjunction with field observation provide good tool in studying LULC modification (Abbas et al. 2010) in relation with species conservation (Elizabeth et al. 2013).

2.2. Application of GIS, GPS and Remote Sensing Technologies

The evolution of Geographic Information Systems (GIS), the Global Positioning System (GPS), and Remote Sensing (RS) technologies has enabled the collection and analysis of spatial data in ways that were not possible before the advent of the computer (Milla et al. 2005). The integration of GIS and RS for ecological mapping and monitoring (Stoms and Estes 1993, Rogan et al. 2003, Rogan and Miller 2006) has become even more important since these data and technologies continue to evolve and ecological issues become more critical (Miller and Rogan 2007). GPS enables the user to determine very accurate locations on the surface of the Earth (Milla et al. 2005). GIS enhances the ability to derive information from remotely sensed data, and such remotely sensed data can describe actual environmental conditions for expedient updating of GIS databases (Miller and Rogan 2007).

The uses of GIS, GPS, and RS technologies, either individually or in combination, span a broad range of applications and degrees of complexity; like simple applications in the location of sampling sites, plotting maps for use in the field (Milla et al. 2005) and more complex applications like LULC mapping and classification (Stoms and Estes 1993, Lein 2003, Daniels 2006), integrated ecosystem measurements (Kerr and Ostrovsky 2003) and change detection (Chen 2002, Shi et al. 2002, Yang and Liu 2005, Forkuor and Cofie 2011). These technologies also have wide application in modelling of habitat distribution (Guisan and Zimmermann 2000), habitat suitability (Thuiller and Munkemuller 2010, Thapa 2012) and species distribution (Guisan and Thuiller 2005, Hernandez et al. 2006).

2.3. Barn owl- General overview and Issues

Bam owls favour open habitat and are often closely associated with agricultural areas (Bent 1961, Campbell and Campbell 1983, Marti 1992). They choose man-made structures over natural sites because of the increased thermal cover and increased security from predators (Andrusiak 1994). For successful nesting, they require open grasslands with high populations of small mammals (Colvin 1985). The area and availability of food items are found to have effect on Barn owls (Ajitha and Vineesh 2015). Poor environmental conditions are thought to be responsible for lowered breeding success (Andrusiak 1994).

Barn owls exhibit a high degree of nest fidelity (Bunn et al. 1982) and nest at the same site (Walk et al. 1999) regardless of its quality even when an adjacent, better quality site becomes available (Taylor 1989). Bunn et al. (1982) observed that a Barn owl had great difficulty in reaching its nest within a building when several obstacles which it normally had to negotiate were removed. Other factors may also influence nest/roost site choice, such as the amount of daytime disturbance at the roost site or the availability of food, mates or predators nearby or ease in finding their roosts in darkness (Andrusiak 1994).

Several studies on Barn owl indicate man-made structures as the most favoured site for nesting and roosting (Campbell and Campbell 1983, Colvin 1984) with highest preference to buildings (Bull 1974, Colvin 1984, Shawyer 1987). The nesting site consists of any suitable hole or structure like cavities in old trees or farm buildings and barns (Barn Owl Trust 2012, Hindmarch et al. 2012). In British Columbia 82% of nest sites in man-made structures are associated with farm buildings (Campbell and Campbell 1983). Shawyer (1987) also pointed out that buildings offer greater protection for young owls in the process of fledging that can be practiced inside the built-up structures. Also natural nests sites like trees are usually destroyed and thus are relatively short-lived compared to nest sites in man-made structures (Colvin 1984, Andrusiak 1994).

Barn owls have been evaluated for rodent pest management through different experimental researches (Duckett 1991, Meek et al. 2003, Wood and Fee 2003). They can adapt to various living conditions in which rodent populations exist (Meyer 2008). High density human developments also attract traditional commensal pest species, such as rats *(Rattus* sp.) and house mice (*Mus musculus*) (Feng and Himsworth 2013). Consequently, the need for pest control, particularly for rats, may be greater in urban settings (Riley et al. 2007, McMillin et al. 2008).

Though Barn owl is one of the most widely distributed birds in the world (Prestt and Wagstaffe 1984), its populations are declining (Andersson 2015) due to habitat loss in many regions, particularly in many other parts of Europe (Bunn et al. 1982, Shawyer 1987, Taylor 1994, Barn Owl Trust 2012) and North America (Campbell and Campbell 1983, Colvin 1985, Marti 1992). The study by Toms et al. (2001) and Sauer et al. (2008) also indicates the constriction of their range and population decline over the last 25 years. Their numbers are reported to have dropped by 69% over the last 50 years in Britain (Toms et al. 2001). Colvin (1985) and Taylor (1994) in their study in Europe and the US suggest degradation, loss and fragmentation of the agricultural landscape as the cause of negative impact on Barn owl populations. Four main factors are argued as the contributor of its population decline. First, the loss of moderate-length grassland is thought to have decreased small mammal populations and reduced prey availability (Colvin 1984, Taylor 1994). Second, old wooden barns have been converted into inaccessible steel barns and old trees have been removed as part of field enlargement programs, resulting in the loss of nesting/roosting sites (Taylor 1994, Ramsden 1998, Hindmarch et al. 2012). Third, the increased urbanization of agricultural areas has increased both the number of roads and traffic volume, and consequently increased Barn owl road mortality (Newton et al. 1991, Andrusiak 1994, Solymár and McCracken 2002, Ramsden 2003, Barn Owl Trust 2012, Grilo et al. 2014). Finally, toxic second-generation anticoagulant rodenticides, metabolize slower in the liver of targeted rodents, exposing Barn owls to the risk of secondary poisoning by consuming poisoned rodents (Newton et al. 1991, Solymár and McCracken 2002, Salim et al. 2014). Bam owl populations are declining in many parts of the world due to changes in agricultural practices and changes in climate (Shawyer 1987, Marti 1992). Study by Almasi et al. (2015) also indicates negative effect of anthropogenic disturbance and intensive agricultural practices on Barn owls.

Illegal trade is the next major threat to the survival of Barn owl. A study by Ahmed (2010) indicates that the Barn owl is the second most commonly observed species in trade. Its eyeballs, skin and feather roots are used for preparing medicines by traditional healers (Chaudhuri 2007) and fresh meat and bones highly priced for their curative use in paralysis, rheumatism and gout (Shrestha 2000). Although the number of owls in trade is unknown in Nepal, their trade has accelerated within the last 15 years and the negative social and cultural beliefs on owls are strong enough to initiate their hunting in several districts (Acharya and Ghimirey 2009). The landscape features in relation to Barn owl and their effects are also yet unexplored in Nepal.

3. MATERIALS AND METHODS

3.1. Study Area

Kathmandu valley is located in the central east part of Nepal between the latitudes of 27º 32’N and 27º 49’N and longitudes of 85º 11’E and 85º 31’E at a mean elevation of about 1,300 m above sea level (Pant and Dangol 2009) in Bagmati zone (Figure 3). Kathmandu, Lalitpur, and Bhaktapur districts together cover an area of 899 km^2 and within it the valley forms an area of 665 km^2 enclosing entire area of Bhaktapur district, 85% of Kathmandu district and 50% of Lalitpur district (Pant and Dangol 2009). The core area of the valley, i.e. area enclosed by Inner Ring Road (IRR) of 27.8 km length, is 82.53 km^2 (Khadka and Shrestha 2008). To decentralize this overcrowded and congested core urbanization, the government of Nepal has initiated the construction of a 71.93 km long Outer Ring Road (ORR) (Thapa 2005) between the existing IRR and the foothills of Kathmandu valley (Khadka and Shrestha 2008).

Administratively, the valley encloses total 21 municipalities and eight Village Development Committees (VDCs) (KVDA 2015). It is composed of five neighbouring urban areas (Kathmandu Metropolitan City, Lalitpur Sub-metropolitan City, Kirtipur Municipality, Bhaktapur Municipality and Madhyapur Thimi Municipality) and surrounding 97 peri-urban and rural villages (Thapa and Murayama 2012). The valley adjoins two Important Bird Areas namely Shivapuri National Park and Phulchoki Mountain Forest along with several other important birding sites (Ghimire 2008). The climate is sub-tropical and cool temperate with maximum of 35.6° C in April, minimum of -3° C in January, 75% annual average humidity and 1400 millimetres average rainfall (Pant and Dangol 2009).

The intensive study is enclosed by two kilometre buffer of proposed ORR of Kathmandu valley (Figure 3). The delineated boundary enclosed total area of 319.79 Km^2. This enclosed Kathmandu Metropolitan City, Lalitpur Sub-metropolitan City, Kirtipur Municipality, Bhaktapur Municipality, Madhyapur Thimi Municipality, 41 VDCs and covered part of 31 peripheral VDCs (Annex 1). On the basis of “Land cover of Nepal 2010” (Bajracharya 2014), the study area enclosed 39% built-up area, 50% farmland, 9 % forest, and 1% each grassland and bare land.

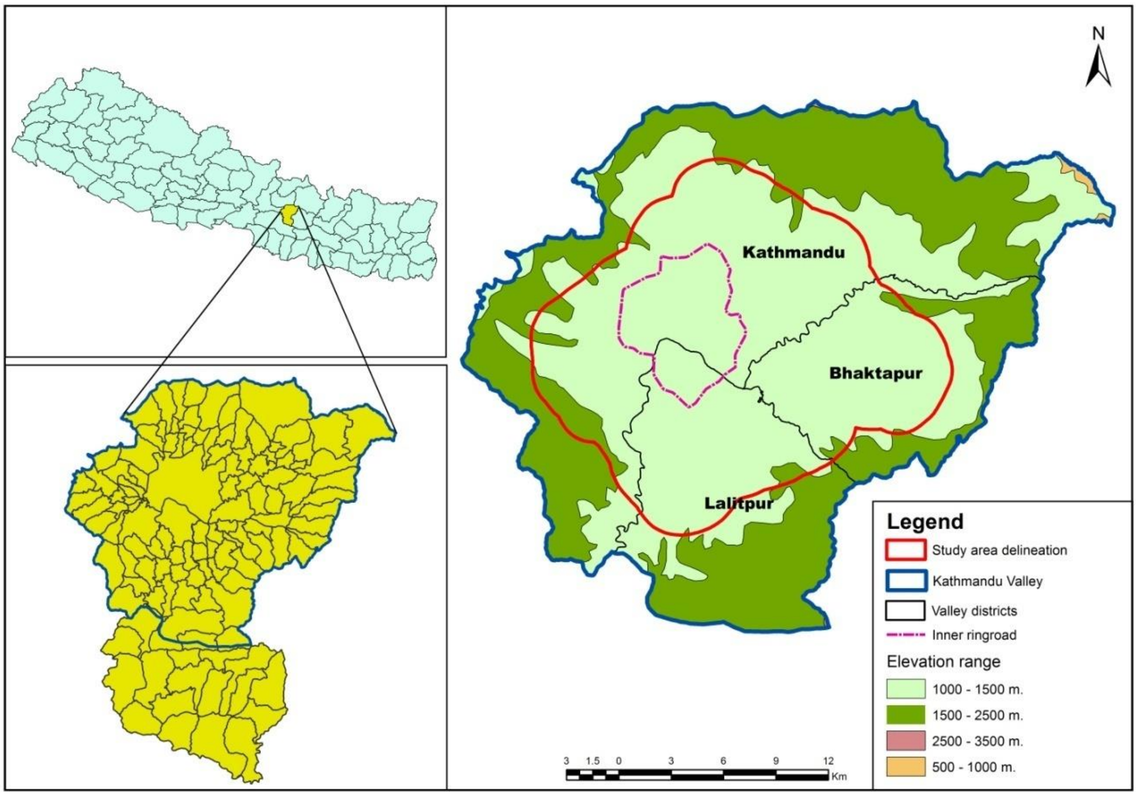

Figure 3. Map showing the study area in Kathmandu valley, Bagmati zone, Nepal

3.2. Methods

3.2.1. Sampling design and plot layout

The study area was divided into square grids of 2 km×2 km (4 km^2) using ArcGIS 10.0 (ESRI, Redlands, California, USA) (Figure 4) based on the reference grid of topographical sheet. The grid size (4 km^2) represented an average home range area of a Barn owl considering the estimated average home range as 3 km^2 (Taylor 1994, Shawyer and Shawyer 1995, Bond et al. 2005). Considering this habitat range, it was assumed that each selected grid had probability of detection of Barn owl if present.

The grids with more than 50% part lying outside the delineated study area were excluded. A total of 81 grids were generated out of which sample grids were selected systematically at an equal interval of 2 km from each other i.e. at an interval of single grid from any selected grid. The sample grids represented the study area in unbiased manner and insured statistical independence of the data. Total 17 (21%) sample grids were selected for sampling purpose. For the purpose of LULC mapping, a buffer (plot) of 1.5 km radius was created from the centre of each sample grid (Figure 4).

In order to ensure unbiased survey of all features within large grid, each grid was further divided into sub-grid of 1 km×1 km, resulting in four sub-grids. The geographic coordinate of the centre point of each sub-grid was uploaded in the GPS (Garmin Etrex10) for field reference. The four central points were at a distance of 1 km from each other. Each central point was buffered with 250 m radius to define intensive survey areas. Remotely sensed habitat variables and topographic maps were studied prior to any field visits.

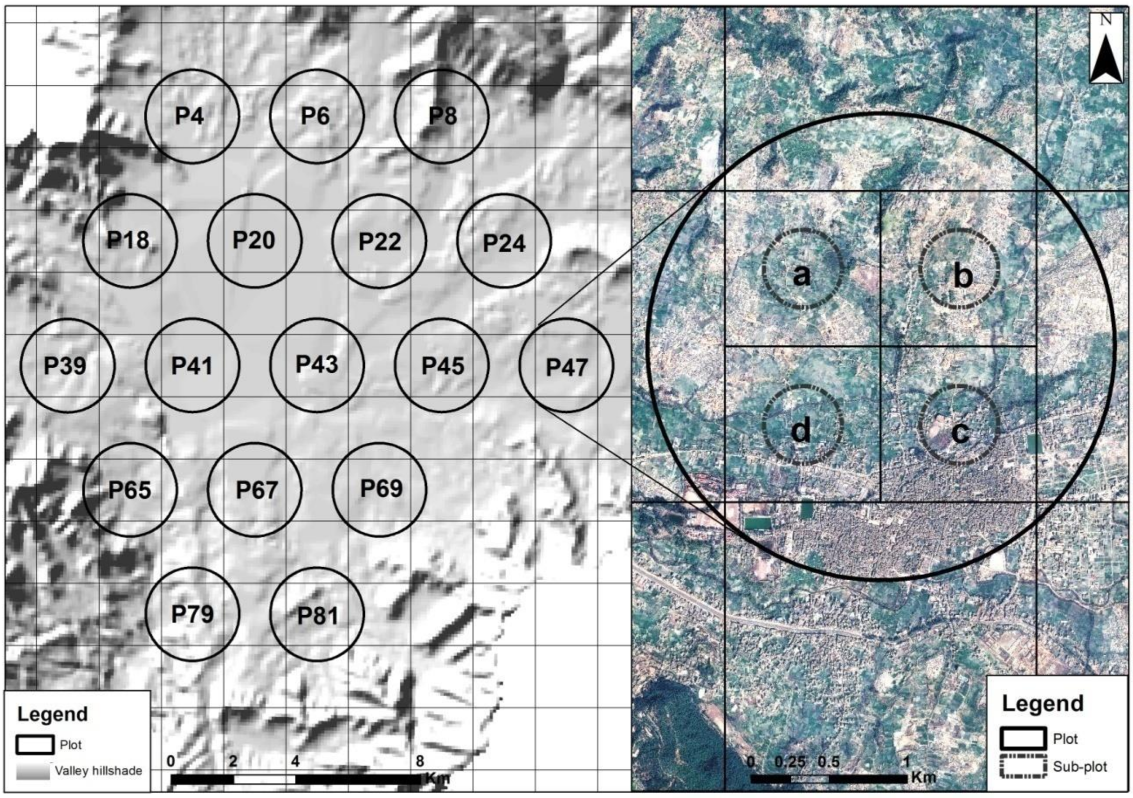

Figure 4. Study area showing total survey plots and single survey plot (P47) with its four sub-plots (site “a”, “b”, “c” and “d”) for intensive survey

3.2.2. Field implementation

3.2.2.1. On-site Scoping Survey

Preparatory work was done during March and April 2014. Preliminary field visits were done during May and June to verify all the selected sites, evaluate the research protocols and ensure all requirements for actual field survey. Field survey started from July till December 2014, and monitoring and record collection was continued till February 2015. The observational surveys for Barn owl were best attempted during the late breeding season, usually between mid June and during July (August to October for late or second broods) and after the owls had vacated their nest site, during the late autumn and winter months (Shawyer 2011). Thus, the survey period was determined as representative of the months for the best observational surveys for Barn owl as mentioned by Shawyer (2011).

On-site scoping survey involved initial walking through the trails within the plots/sub-plots during daylight hours. The potential sites of Barn owl were assessed by interaction with locals, farmers (Bunn et al. 1982, Shawyer 1987), local bird watchers and review of available records. All likely roosting and nesting sites along the trails, such as old wooden buildings, religious monuments, barns, tall structures with openings near roof and old single standing trees in farmlands (Bunn et al. 1982, Taylor 1994), were surveyed. Binoculars (Bushnell 10X42, Aerolite 7X50) were used to view and scan structures/locations at some distant. Identified potential areas were recorded for further investigation of occupancy of Barn owl. Opportunistic surveys were done along the walking trail and outside the plots as well.

3.2.2.2. Investigative Field Survey

A detection–non-detection survey (Roberts 1991, MacKenzie et al. 2006) was used to estimate occupancy probability of Barn owl and predict best supported model for its presence at plot and sub-plot level. The structures along the walking trail and area within the sub-plots, identified during Scoping survey, were rigorously searched for the signs of presence of the Barn owl following Taylor (1994), Shawyer and Shawyer (1995), Bond et al. (2005) and Shawyer (2011). The signs of presence included live sighting or calls of adults/chicks and indirect evidences such as moulted feathers, egg shells, white droppings, and pellets. Pellets are undigested parts regurgitated at least daily, are distinctively ovoid, glossy black, and about 25 x 50 mm in size (Burton 1973). Local assistance was also used to identify potential sites within each plot. In the sub-plots with inconclusive evidence of Barn owl occurrence, visual and aural survey, aided with play-back recordings were conducted (Shawyer 2011) for an hour before and after sunset (Toms et al. 2000) i.e. approximately from 1700 to 1900 hours. The call survey was done at appropriate location around the central point of the sub-plot (250 m radius) considering the maximum detection (visual or aural) of virtually all individuals of most species in any habitat is less than 250 m (Ralph et al. 1995, Pryde and Greene 2015). Portable Bluetooth sound player (BE 13) was used for play-back survey with recorded calls from xenocanto.org. Digital Flashlight and LED headlights were used during evening and night time observation. The sightings and indirect evidences of Barn owl were documented as photographs using Camera (Canon, 16.1 Megapixel, Zoom lens- 65X).

At least one local correspondent was employed to monitor any Barn owl activities within each sub-plot. This was done so that the presence was not underestimated at any plot. The local correspondents were asked to document the evidence as photographs and/or call records. Each plot was re-visited to collect the evidences, monitor the identified sites and record GPS points of identified sites, nearby built-up, farms, rivers, roads and temples. The identified sites were defined as Potential Nest Site (PNS), Temporary Rest Sites (TRS), Active Roost Site (ARS) or Occupied Breeding Site (OBS) as considered by Barn Owl Survey Methodology and Techniques by Shawyer (2011) (Annex 2).

3.2.3. LULC mapping

The topographical sheet maps at 1:25000, produced by Survey Department, and Google Earth image of 2014 (Google Inc. 2015) were used to extract general information on locations and LULC attributes within the study area. Open Street Map data licensed under the Open Database License (ODbL) and Garmin Basecamp Version 4.4.6 were used to manage GPS data from the field survey and as additional reference information during LULC mapping. The lengths of roads, rivers and temple sites, within the study area, were mapped on satellite image of Kathmandu valley (IKONOS, 0.5 m resolution) in ArcGIS 10.0.

3.2.3.1. Plots

For the purpose of LULC mapping and extraction of LULC attributes for each plot, a buffer of 1.5 km radius was placed on the satellite image of Kathmandu valley in ArcGIS 10.0. A dot grid matrix (FAO 2008, Pretzsch 2009, Head 2010, Cushing and Tappan 2015), with a distance of 50 m between the dots, was placed on the image. Separate shapefiles were created to map each LULC feature; built-up, grass cover, tree cover and water body (Annex 3). Each dot was visually observed and the LULC feature, represented on the satellite image, was coded with a distinct colour/symbol. Different colour/symbol was assigned for different LULC feature. The lengths of roads, rivers and number of temples were clipped by each plot from their respective digitized layers using clip (Analysis) tool of ArcGIS.

3.2.3.2. Sub-plots

For mapping in each sub-plot of 250 m radius, separate shapefiles were created for separate LULC feature; built-up, grass cover, tree cover and water body (Annex 4). Editor tool was used to digitize each area within 250 m area. The lengths of roads, and rivers were clipped by each sub-plot from their respective digitized layers.

3.3. Data analysis

3.3.1. LULC attributes analysis

Total dots for each LULC feature within the plot were summed and percentage was calculated for each plot following Head (2010).

$$\text{LULC percentage} = \frac{\text{Total dots of particular LULC feature within the plot}}{\text{Total dots of all LULC features within the plot}}$$

In case of sub-plots, area was calculated for each digitized LULC feature. Similarly, length of clipped roads and rivers were calculated for each plot and sub-plot. The GPS data recorded during the field survey were also compiled.

3.3.2. Occurrence of Barn owl and its potential habitats

The recorded information from the field survey was used to map and analyze the occurrence and potential habitats of Barn owl in the study area.

3.3.3. Effects of LULC on occurrence of Barn owl

Detection histories were constructed for each plot, where ‘1’ indicated detection of the species/species sign and ‘0’ indicated non-detection. Presence data obtained from each plot and sub-plot were used to determine the general distribution pattern and study effects of LULC on their occurrence.

3.3.3.1. Plot- level

At plot-level, occurrence of Barn owl detected during the entire survey was pooled across each of the 17 plots and calculated as a percentage based on the number of sites in each plot. One-way ANOVA was run to determine any differences between Barn owl occurrence and built-up level in program R (R Core Team 2015). Occupancy models in PRESENCE version 9.7 (Hines 2006) was used to determine if the site parameters-percentage of built up, grass cover, tree cover, length of roads, rivers and number of temple (Annex 3) affected the probability that Barn owl would be present at a survey point. Single species-single season occupancy model was used to estimate the occupancy (Mackenzie et al. 2002, 2006) using method of maximum likelihood. Multiple models were run, the models ranked and model weights calculated using Akaike's Information Criterion (AIC) (Burnham and Anderson 2002). In a model set, the AIC weights were summed to one for all members, and the weights represented measure of the appropriateness of a given model relative to other models in the model set.

3.3.3.2. Sub-plot level

A logistic regression model was run in program R to examine how land use within sub-plot of 250 m radius influenced occurrence of Barn owls at site level. For this analysis, the landscape variables were included were area of built up, grass cover, tree cover, length of roads and rivers (Annex 4). For the analysis, a candidate model set was created consisting of logistic regression models with all possible combinations of the landscape variables and a null model, a logistic regression model containing a single parameter, the constant. No interaction terms were considered. Akaike's Information Criterion (AIC) was used to rank and identify the best-supported models within the model set (Burnham and Anderson 2002). The parameter estimates and their associated standard errors of the explanatory variables were also computed which were used to assess the relative influences of the explanatory variables present in the best-supported models on the dependent variables.

3.4. Post-earthquake Scoping Survey

After the massive earthquake on 25 April 2015, a post-earthquake scoping survey was done from mid May till July for the purpose of evaluating the immediate effects of earthquake on already identified roost and nest sites of Barn owl in Kathmandu valley. The conditions of built-ups of all ARS and OBS, which were identified during the study period before the earthquake, were documented.

4. RESULTS

4.1. Land Use and Land Cover Mapping

Land Use and Land Cover (LULC) mapping of Kathmandu valley consisted of seven attributes: built up area, grass cover, tree cover, water body, major roads, rivers and temples. A total of 261.95 km major roads, 187.68 km rivers and 216 temples were digitized and mapped within the study area (Figure 5).

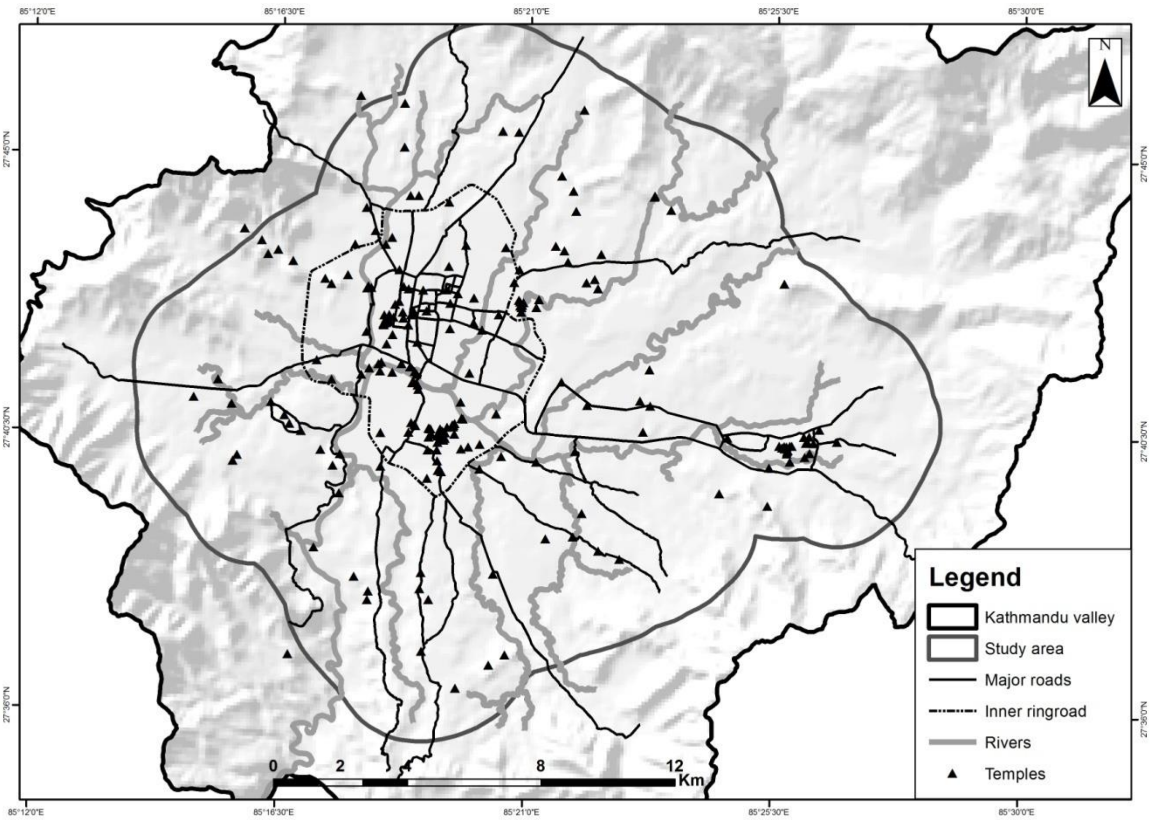

Figure 5. Study area with digitized roads, rivers and temples

4.1.1. Plot level

The survey plots contained 52% of grass cover followed by built-up (41%), tree cover (6%) and water body (1%). Among the 17 plots, highest percentage of built-up area was estimated in plot P20 (83%), grass cover in plot P79 (80%), tree cover in plot P8 (26%) and water body in plot 43 (3%) (Figure 6). The proportion of built-up percentage among the plots increased from peripheral area to the core of the valley and reverse for the grass cover (Figure 7).

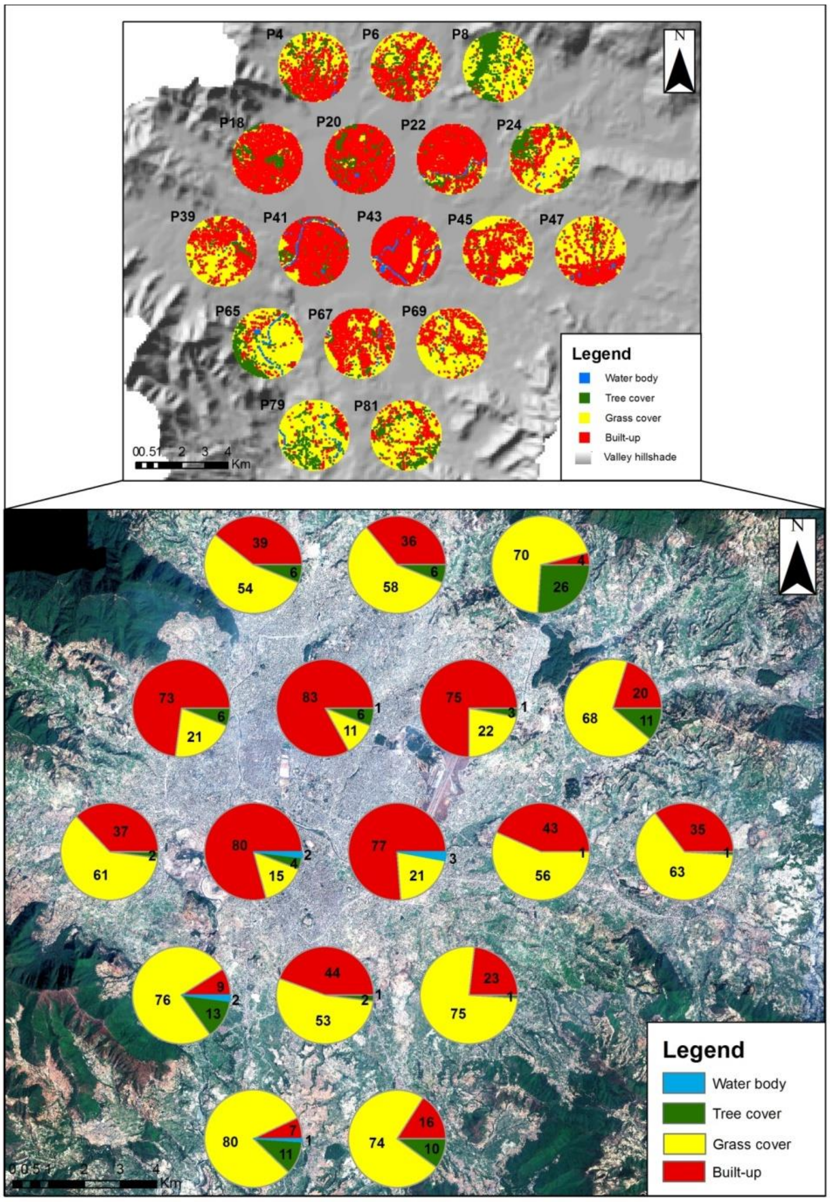

Figure 6. Percentage of digitized LULC features within the study plots

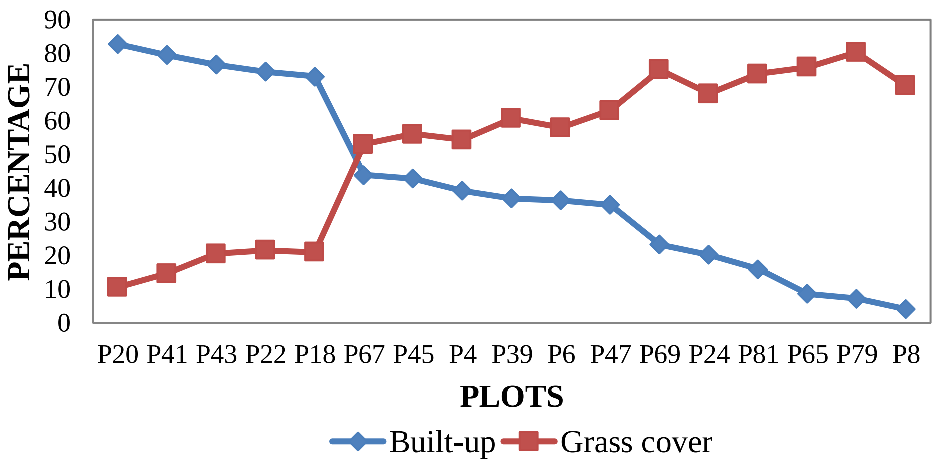

Figure 7. Proportion of built-up and grass cover in survey plots

Based on the proportion of built-up area, the plots were classified into three categories of urbanisation: low (Rural); containing < 30 % built-up (n=6), medium (Sub-urban); containing between 30 and 60% built up (n=6) and high (Urban); containing > 60% built-up (n=5) (Table 1).

Table 1. Categories of urbanisation levels in the plots.

1. High (Urban)					
Plot	P20	P41	P43	P22	P18
Built-up %	83	80	77	75	73

2. Medium (Sub-urban)						
Plot	P67	P45	P4	P39	P6	P47
Built-up %	44	43	39	37	36	35

3. Low (Rural)						
Plot	P69	P24	P81	P65	P79	P8
Built-up %	23	20	16	9	7	4

The survey plots included total 156 km of major road length, 91 km of river length and 91 temple locations. Among the plots, maximum length of river was present in plot P81 (11%), maximum road length in P20 and P41 (16%) and maximum number of temples in P41 (23%) (Annex 5).

4.1.2. Sub-plot level

At site level total 68 sub-plots were digitized, each with 250 m radius buffer area (Figure 10). The site level digitization resulted into total 4.86 km^2 of built-up, 7.62 km^2 of grass cover, 0.78 km^2 of tree cover, 0.08 km^2 of water body, 40.08 km of roads and 9.05 km of rivers (Annex 6).

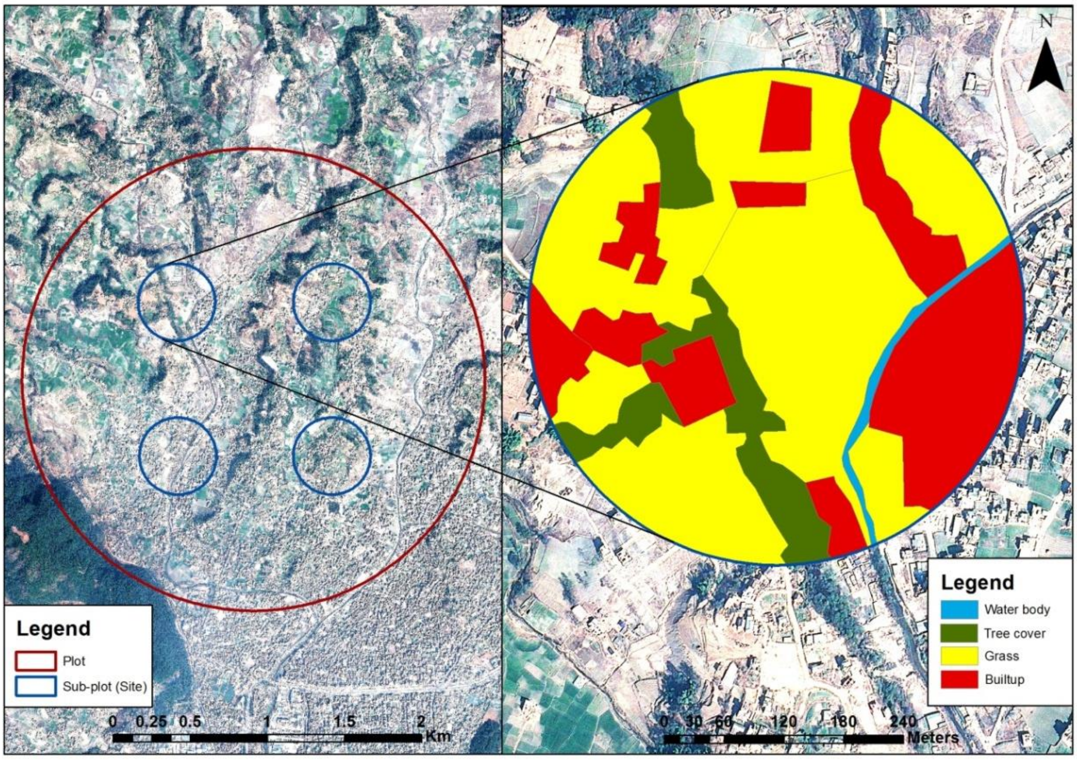

Figure 8. Sub-plot level digitization of LULC of the study area; (site a) of plot P4

4.2. Occurrence of Barn owl and its potential habitat

Out of 17 survey plots, Barn owl was recorded in 11 plots. Plot P47 had the highest (13) records followed by plot P39 (11) and P41 (9) (Figure 9). Total sixty nine sites with occurrence of Barn owl, were located during the survey period in Kathmandu valley. Out of 69, 50 identified sites were located within the survey plots and remaining 19 were identified outside the plots. Among the 50 sites, 27 (54%) sites were identified as TRS, 10 sites (20 %) as ARS and seven sites (14 %) as OBS. Four sites (8%) had record of dead specimen and two sites (2%) with live Barn owl in captive stage. They were found captured for selling purpose and for fun. Among the death records, one seemed as collided with vehicle (at plot P43), the other was killed by dog (at plot P6), and the death of remaining two was unclear (at plot P41 and P22). Additional nine TRS, six ARS and four OBS were recorded outside the study plots as well during the survey period. From among above encounters, there were two rescue cases of Barn owl; one at plot P43 which later died during treatment and the other at plot P41 which was released safely. The occurrence survey using call count method for an hour before and after sunset i.e. 1700 to 1900 hours, resulted no any response of Barn owls at any site. However indirect sign surveys at potential sites were found effective to study their occurrence.

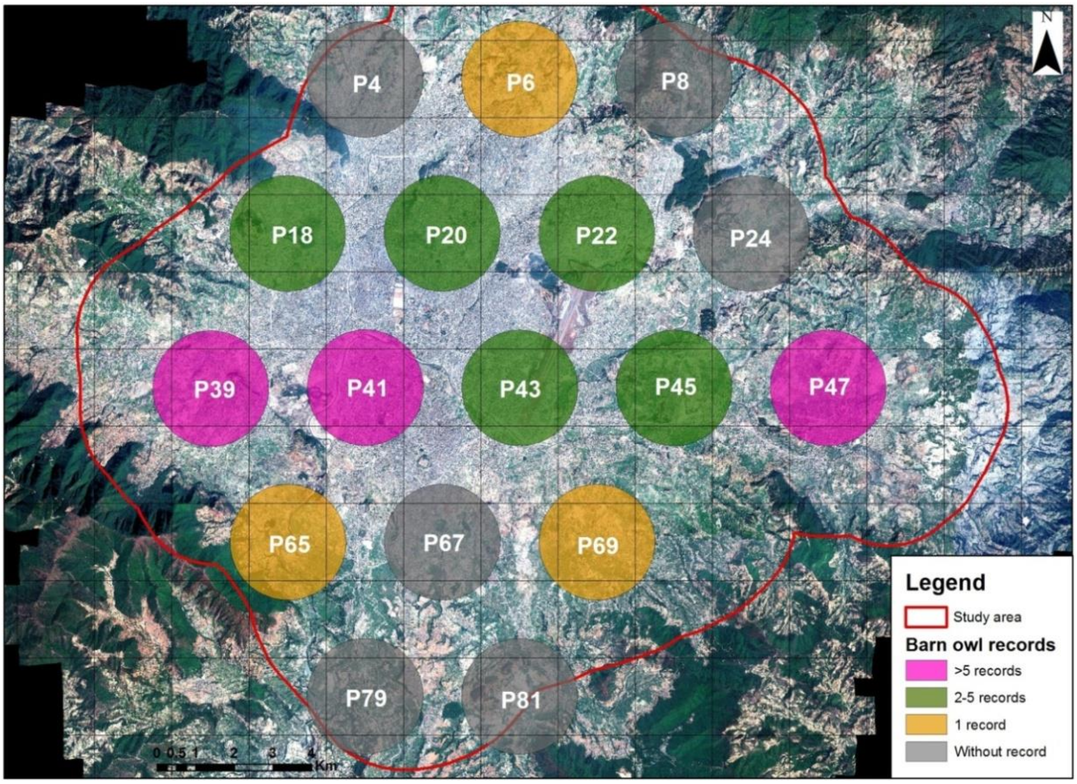

Figure 9. Survey plots with record of Barn owl during survey period

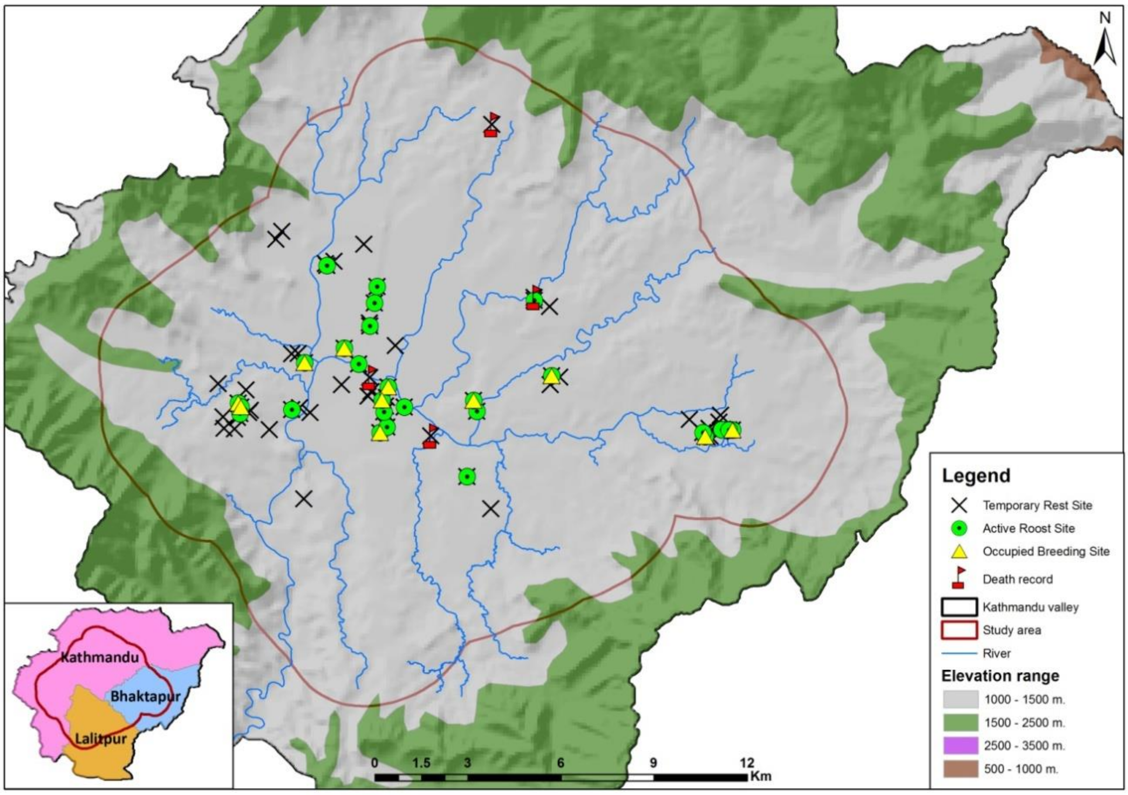

Figure 10. Occurrence of Barn owl in Kathmandu valley with locations of Temporary Rest Site (TRS), Active Roost site (ARS), Occupied Breeding Site (OBS) and locations with record of dead specimen (2014)

Buildings made up the greatest proportion (51%) of Barn owl occupied structures followed by compound walls (10%) and temples (8%). All but four of the sites, used by Barn owl, were natural sites (trees, 6%) which were used as TRS (Figure 11).

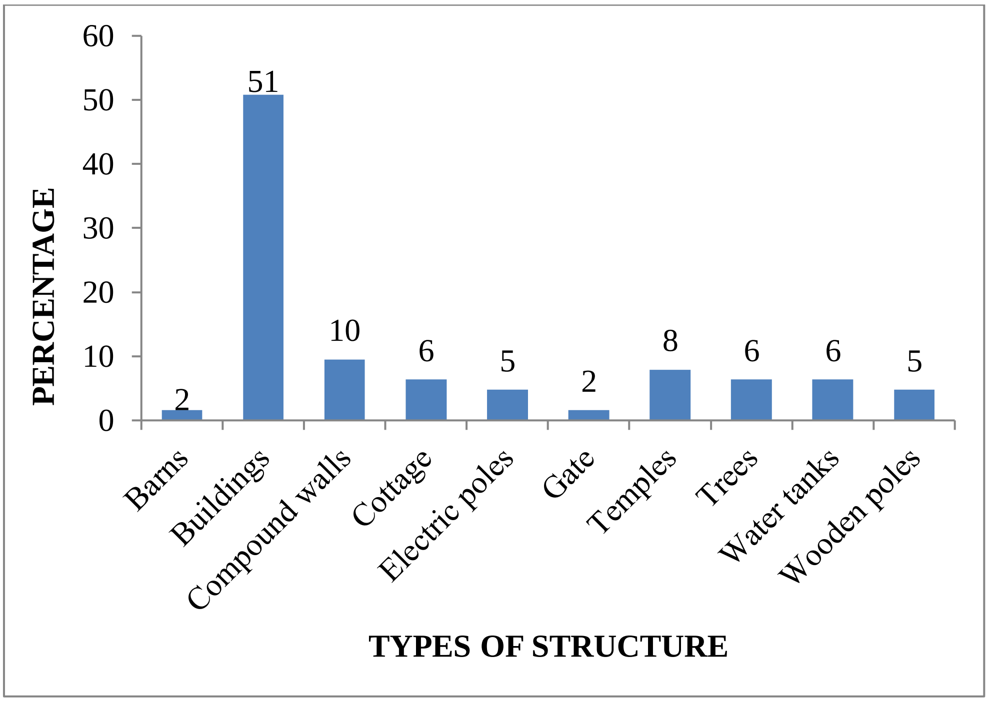

Figure 11. Proportions of types of Barn owl nest/roost/resting sites in Kathmandu valley

The most common ARS was in buildings (15), followed by temples (5) and cottage (3). Roof holes of both wooden and concrete buildings were used as ARS by Barn owls. Old buildings with wooden roofs provided cavities easily available for roosting and nesting. In case of concrete buildings, roosts and nests were found inside the damaged roofs with holes, roofs with unsealed cavities or in under construction buildings that provided open space. In some cases, unused chimneys were also used for nesting. The Barn owls were displaced when the chimneys were reused by humans.

Most of the man-made structures used by Barn owl were made up of a combination of concrete and wood (54%) and wooden structures only (24%) followed by metal (12%) (Figure 12). All identified OBS were in the man-made structures. Out of 11 OBS, seven were in building structures (six concrete, one wooden), two in temples (wooden), one in cottage (wooden) and one in compartment inside entrance gate (wooden).

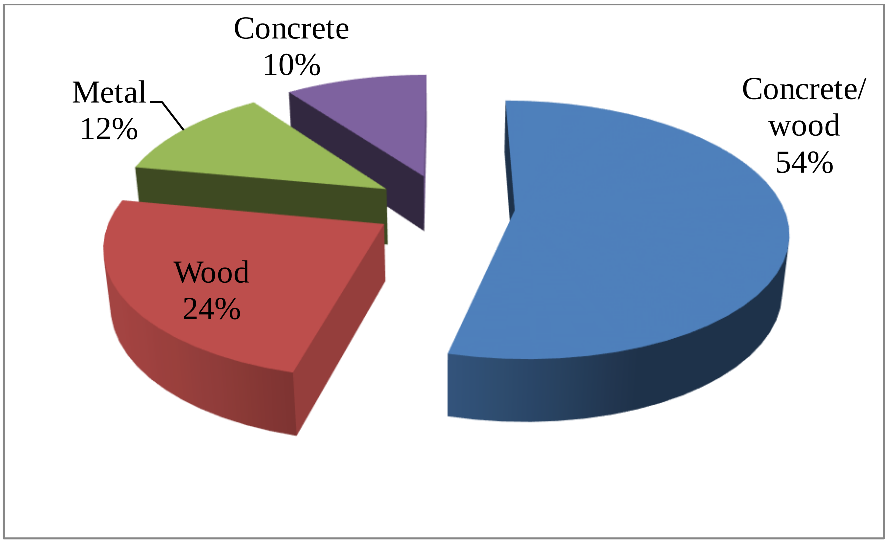

Figure 12. Proportions of man-made structures used by Barn owl for nesting and roosting.

4.3. Effect of LULC on occurrence of Barn owl

4.3.1. Plot-level

4.3.1.1. Association with built-up level

The assumption of normality and the homogeneity of variances F(2, 14)= 0.543, p= 0.593 were found tenable for the data. The occurrence of Barn owl was significantly affected by built-up level in the plots F(2, 14)= 5.049, p< 0.05. Tests revealed significant pair wise differences between the mean scores of occurrence of Barn owl at low built-up level (M= 8.33±12.91, n= 6) and at high built-up level (M= 45±20.92, n= 5), p< 0.05. Occurrence of Barn owl at medium built-up level (M= 25±22.36, n= 6) did not significantly differ from the other two levels, p> 0.05 (Figure 13).

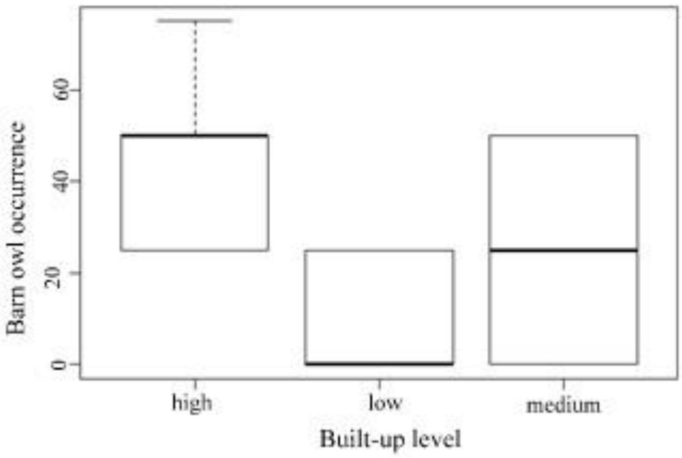

Figure 13. Description of level of built-up and occurrence of Barn owl in Kathmandu valley

4.3.1.2. Occupancy estimation

The proportion of sites that were surveyed where the Barn owl was detected at least once, i.e. naive occupancy estimate was found to be 0.6471 (sighted in 11 blocks out of 17). The null model performed less support as indicated by the summary statistics ranked based on AIC value (Table 5). Of the entire model analysed tree cover had the highest level of support with highest weight (wi) indicating the best model among the candidate set. Additive models of tree cover percentage with number of temples, length of river, length of road, grass cover and built-up percentage were also found to be strong candidate models (ΔAIC = <2.0) (Table 5). Similarly, the combined effect of more than two parameters like combined model constituting built-up, grass cover, tree cover and river also had a reasonable level of support having a substantial amount of AIC weight though they were not the best model.

Table 2. Summary of probability of occupancy (Ψ) and detection (.) model selection results for Barn owl in Kathmandu valley.

Model	K	ΔAIC	wi	Model Likelihood	-2*LogLike
Ψ(TREE),p(.)	2	0.0	0.067	1	74.31
Ψ (TREE,TEMPLE),p(.)	3	0.47	0.0529	0.7906	72.78
Ψ (TREE,RIVER),p(.)	3	0.52	0.0516	0.7711	72.83
Ψ (TREE,ROAD),p(.)	3	1.05	0.0396	0.5916	73.36
Ψ (GRASS,TREE),p(.)	3	1.1	0.0386	0.5769	73.41
Ψ (BUILT,TREE),p(.)	3	1.16	0.0375	0.5599	73.47
Ψ (BUILT,GRASS,TREE,RIVER),p(.)	5	1.39	0.0334	0.4991	69.7
Ψ (BUILT,GRASS,TREE),p(.)	4	1.69	0.0288	0.4296	72.00
Ψ (BUILT,GRASS),p(.)	3	1.73	0.0282	0.4211	74.04
Ψ (TREE,RIVER,TEMPLE),p(.)	4	1.79	0.0274	0.4086	72.1
Ψ (.),p(.)	2	1.89	0.026	0.3887	76.2
Ψ (BUILT),p(.)	2	1.96	0.0251	0.3753	76.27
Ψ TEMPLE),p(.)	2	2.0	0.0246	0.3679	76.31

*Given are the Model numbers as referenced in Analysis; occupancy rate (Ψ), detection probability (p), Constant (.), number of parameters in the model (K), relative difference in AIC values compared to top ranked model (Δ AIC), AIC model weights (W), tree cover percent (TREE), grass cover percent (GRASS), built-up percent (BUILT), length of river (RIVER), length of road (ROAD).

4.3.1.3. Covariates Weight

Tree coverage showed greater weight (37.68%) in determining occupancy of the Barn owl for top models and 66.65% for all sets of model. Build-up area, number of temples and grass cover showed 10-15% in top models and 39-42% in all set determining the occupancy of the Barn owl. Length of river and road showed lesser weight in determining the occupancy in both top and all sets of model (Table 3).

Table 3. Support for each covariate in top and all models.

	TREE	BUILD	TEMPLE	GRASS	RIVER	ROAD
Top Set	37.68%	15.22%	12.90%	10.08%	7.90%	3.96%
All Set	66.65%	42.70%	38.92%	39.67%	30.20%	28.68%

*BUILT: built-up percent, GRASS: grass cover percent, TREE: tree cover percent, ROAD: length of roads (km), and RIVER: length of rivers (km).

Summed model weight indicated good support for the covariate tree cover and considerably less support for the other covariates (Table 4). Occupancy of Barn owl was negatively correlated with tree cover (β= -2.20), grass cover (β= -1.00) and length of river (β = -0.53). Similarly, occupancy of Barn owl was positively correlated with build-up area (β= 1.25), number of temples (β= 1.55) and length of road (β=1.12).

Table 4. Covariates influencing occupancy of Barn owl ranked on the basis of summed model weights, with averaged β coefficients and associated standard errors (SE).

Covariates	Model Weight	Beta co-efficient
TREE	1	-2.2 ± 1.17
BUILD	0.38	1.25 ± 0.69
TEMPLE	0.37	1.55 ± 1
ROAD	0.29	1.12 ± 0.78
GRASS	0.2	-1 ± 0.63
RIVER	0.07	-0.53 ± 0.58

4.3.2. Sub-plot level

Out of 68 sites surveyed, Barn owl was recorded in 10 sites (14.71%). There were difference in the amount of LULC features between sites with occurrence and non-occurrence sites of Barn owls (Table 5).

Table 5. Summary of the amounts of different LULC features between sites (n=68) with occurrence and non-occurrence of Barn owl in Kathmandu valley at site-level. Means are presented ± SD.

Variables	Occurrence (10)	Non-occurrence (58)	t-statistics	p-value
BUILT	0.1050 ± 0.0552	0.0656 ± 0.0656	-1.788	0.317
GRASS	0.0853 ± 0.0582	0.1167 ± 0.0644	1.44	0.464
TREE	0.0047 ± 0.0067	0.0127 ± 0.0226	1.101	0.171
ROAD	0.2375 ± 0.1604	0.6501 ± 0.5803	2.221	0.003
RIVER	0.1942 ± 0.2608	0.1225 ± 0.2227	-0.917	0.207

*BUILT: amount of built-up area (km^2), GRASS: areas of grass cover, fields and grounds (km^2), TREE: amount of tree cover (km^2), ROAD: length of roads (km), and RIVER: length of rivers (km).

Based on the AIC analysis, four models received strong support ($\Delta AICc < 2$), with a combined wi = 0.45 (Table 6). All of the models with strong support, including the best supported model, included the length of road as an explanatory variable. As a whole, this best supported model explained 13% of the variance in the occurrence of Barn owl. Models without road as variable received little support. The inclusion of river variable to the second-highest rank model showed greater strength than the top-ranked model, accounting for 15% of the variance in Barn owl occurrence. The third-highest ranked model, comprising tree cover and road length, accounted for 14% of the variation in the Barn owl presence which also showed greater strength than the top-ranked model. The fourth-highest ranked model accounted for 13% variance.

Table 6. AIC ranking (by wi) of candidate models examining how LULC variables influence the occurrence of Barn owl in Kathmandu valley at site-level.

Models	K	N	Loglik	AICc	ΔAICc	wi
ROAD	2	68	-24.84	53.87	0	0.17
ROAD + RIVER	3	68	-24.23	54.83	0.96	0.11
TREE + ROAD	3	68	-24.32	55.02	1.15	0.1
BUILT + ROAD	3	68	-24.73	55.83	1.96	0.07
GRASS + ROAD	3	68	-24.81	55.99	2.12	0.06
TREE + ROAD + RIVER	4	68	-23.81	56.26	2.38	0.05
BUILT + ROAD + RIVER	4	68	-24.06	56.75	2.88	0.04
BUILT + TREE + ROAD	4	68	-24.26	57.15	3.28	0.03
BUILT + GRASS + ROAD + RIVER	5	68	-23.45	57.87	3.99	0.02
BUILT + TREE + ROAD + RIVER	5	68	-23.69	58.36	4.48	0.02
GRASS + TREE + ROAD + RIVER	5	68	-23.72	58.41	4.54	0.02
BUILT	2	68	-26.9	57.98	4.1	0.02
TREE	2	68	-27.2	58.58	4.7	0.02
NULL	1	68	-28.39	58.85	4.98	0.01

*Variables in the models are abbreviated as follows: BUILT: amount of built-up area (km^2), GRASS: areas of grass cover, fields and grounds (km^2), TREE: amount of tree cover (km^2), ROAD: length of roads (km), and RIVER: length of rivers (km). Models are described using the same abbreviations as used in table 1. All variables are measured within 250 m radius of each site.

The weighted parameter estimate for the road variable was negative (-2.80) (Table 7). The length of river, tree cover patch and built-up area were included in remaining strongly supported models (ΔAICc < 2) (Table 6). Built-up (8.87) and river (1.25) had its weighted parameter estimate positive where as it was negative in case of tree cover (-52.07). None of the model with strong support (ΔAICc < 2) included grass cover and its parameter estimate was negative (-7.54) (Table 7).

Table 7. Correlation of coefficients, weighted estimates and standard errors for each variable included in the candidate models examining how LULC variables influence the occurrence of Barn owl in the sample sites in Kathmandu valley.

Variable	Coefficients	Estimate	z-value	Pr(>|z|)
INTERCEPT	-	-1.758 ± 0.342	-5.134	0.000
BUILT	-0.820	8.871 ± 5.177	1.714	0.087
GRASS	-0.810	-7.540 ± 5.354	-1.408	0.159
TREE	-0.540	-52.073 ± 43.167	-1.206	0.228
ROAD	-0.720	-2.803 ± 1.438	-1.950	0.051
RIVER	-0.580	1.248 ± 1.367	0.913	0.361

4.4. Post-earthquake Scoping Survey

Out of the total 16 ARS identified during the survey period, four were damaged completely by the earthquake with five partially damaged. Remaining seven were unaffected. Out of total 11 OBS, two were completely damaged, one partially damaged and remaining eight were unaffected. Among the plots with maximum occurrence of Barn owls (P39, P41 and P47), plot P47 had most of its identified roosting and nesting sites demolished. Breeding was not found in any of the sites visited during the post-earthquake survey. Nine nesting sites had absence of Barn owl activities with presence in two sites; in plot P39 and P41.

The ruined roosting and nesting sites were mostly old structures made of wood and brick. Concrete buildings were the unaffected sites. Though the Barn owl nesting and roosting sites was mainly in buildings than other structures and 31% (5) of those buildings were affected, proportion of damage was high in sites present in temples, cottages and barns (Figure 14).

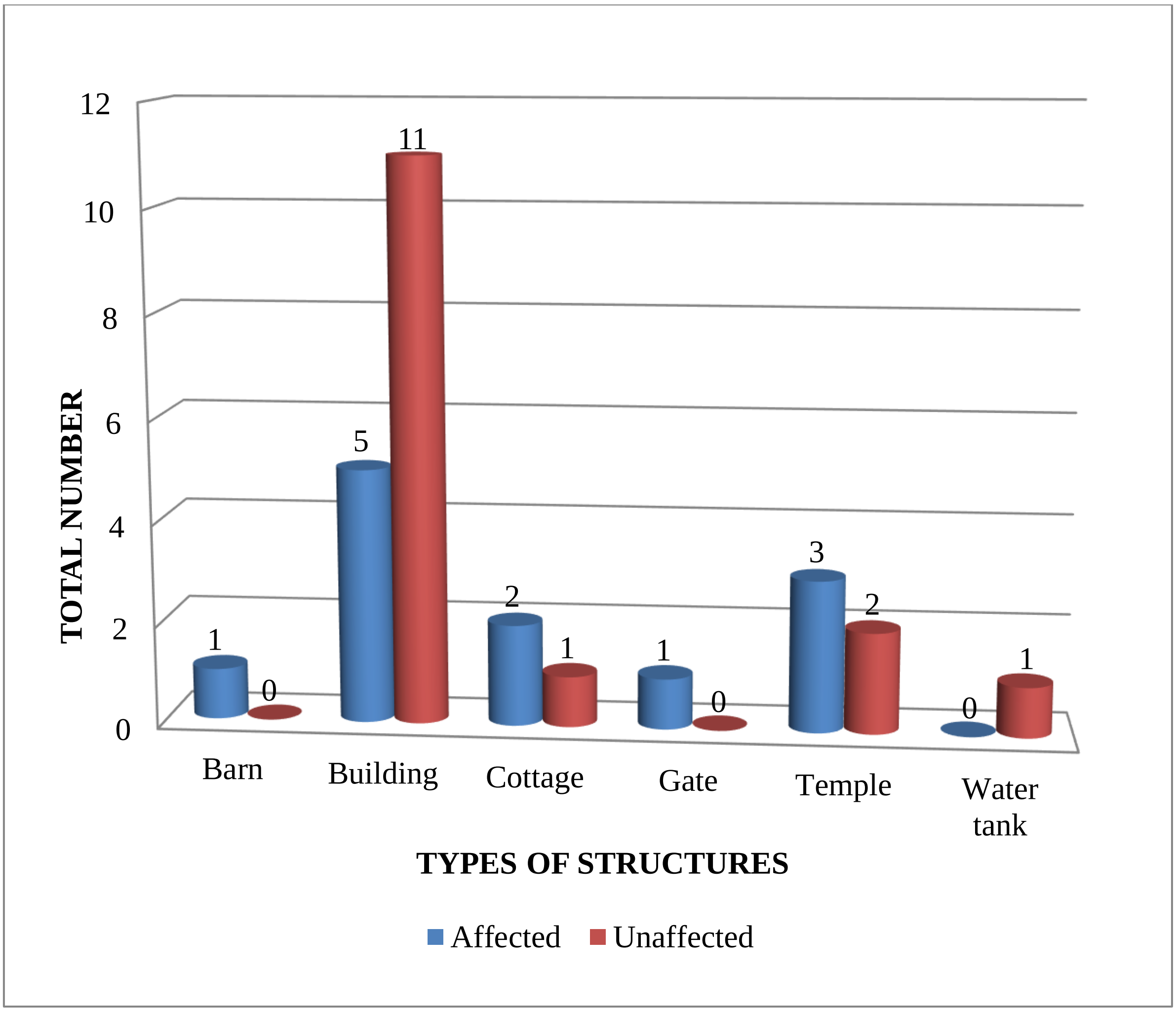

Figure 14. The structures used by Barn owl; affected and unaffected by the April earthquake

A number of Barn owls were found injured or stressed and rescued from different locations in Kathmandu valley within the few months after the major earthquake (April 2015); at Pulchowk (May), Kalanki (June), Panipokhari (July), Imadol (July). The rescued Barn owls within Kathmandu district were handed to District Forest Office (DFO), Hattisar, Kathmandu by the Police Patrol Team and were released in safe locations. Other rescued Barn owls were checked for injuries and released safely during evening at nearby safe location; away from major roads and dense built-up. Barn owls were sighted during the day time at several locations which were mostly found mobbed by crows and drongos; at Bhaktapur (June), Pulchowk (July), Samakhusi (July), Chabahil (August) and Kirtipur (August).

Though no Barn owls were found dead during the post-earthquake survey (May and July 2015), the rate of record of stressed Barn owls was almost double than that observed during the study period (May 2014 to February 2015).

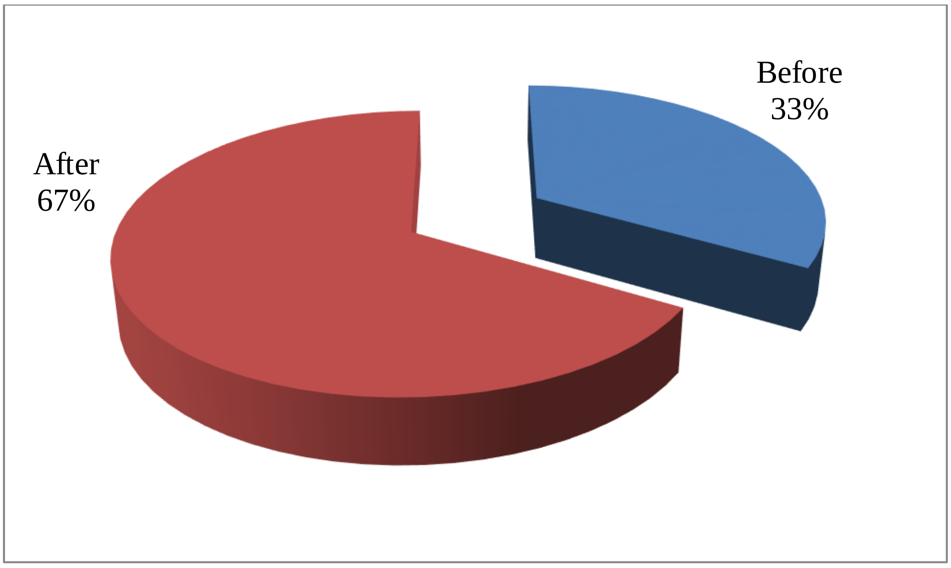

Figure 15. Percentage of record of stressed Barn owl; before and after the April earthquake

5. DISCUSSION

5.1. Land Use and Land Cover mapping

The intent of this study was to derive LULC features of Kathmandu valley to incorporate in model building for occupancy of Barn owl and assess the effects of the LULC on its occurrence. Manual digitization and mapping of LULC features on high resolution IKONOS image produced the current map of major road, river networks, temples and the proportion of built up, grass cover, tree cover and water body within Kathmandu valley. Though laborious, time consuming and expensive, manually digitized data are often more accurate than classified data, since the person digitizing can visually identify the LULC features and cross-check class assignments with other valid data sources, such as field notes (Cunningham 2006). Errors can occur when patches of LULC class are small relative to the cell size of the data or different LULC features are spectrally similar or when landscapes are heterogeneous (Smith et al. 2002) as in urban cities (Mathieu et al. 2007). Today very high resolution satellites images like Ikonos images are capable of providing spatial details compatible with urban mapping and successfully map the urban land cover, impervious surfaces, roads and buildings (Sawaya et al. 2003). Recent advancements in GIS and Remote Sensing technologies provide powerful tool for mapping LULC, and these technologies in conjunction with field observation provide good tool in studying LULC (Abbas et al. 2010) in relation with species conservation (Elizabeth 2013).

5.2. Occurrence of Barn owl and its potential habitats

The occurrence of Barn owl in Kathmandu valley is patchy and random. The concentration is high in the plots located in municipalities; in mid-section of the valley extending from East to West. Such kind of clumped distribution is a result of aggregation of individuals in response to various ecological factors like habitat differences, daily or seasonal weather change, reproductive phenomenon or the social attractions (Odum 1996). Occurrence is thin and scattered when moving outwards from these plots i.e. towards the periphery of the valley. This occurrence pattern may be influenced by the nest and roost site availability, prey abundance and habitat suitability. The records of Barn owl are sketchy, probably due to the bird's nocturnal habits and secretive behaviour (Grimmett et al. 1998).

In Kathmandu valley, Barn owl appears to depend heavily on man-made structures as TRS, ARS and OBS. Buildings comprise highest percentage among structures used by Barn owl followed by temples. Use of man-made structures by Barn owl is common throughout the world (Bull 1974, Campbell and Campbell 1983, Colvin 1984, Shawyer 1987, Andrusiak 1994) because buildings provide a number of advantages over natural cavities (Andrusiak 1994). One of the important advantages is insulation from cold weather (Walsberg 1986) as Barn owls have little fat reserves and are sensitive to cold weather (Johnson 1974). Buildings also offer greater protection for young owls in the process of fledging (Shawyer 1987). Though Barn owls prefer natural sites like tree cavities in warm climates (Campbell and Campbell 1983), the trees with cavities are very scarce in Kathmandu valley. The Barn owls are considered to have historical nest sites and shows nesting fidelity (Taylor 1989). Since trees don't provide safe site for the long run (Colvin 1984) and man-made sites are much more permanent than natural sites for the Barn owls, they frequently use the man-made structures (Andrusiak 1994).

The man-made structures used by Barn owl in Kathmandu valley are mainly made of combination of concrete and wood which is little contradictory with the report of Andrusiak (1994) in British Columbia. His study had revealed wood as the most used material in man-made structures preferred by Barn owls, followed by combination of wood and metal. In Kathmandu valley, buildings with cement-bounded brick/stone and cement concrete are in popularity (CBS 2012) and with the growing urbanisation the old mud and wood houses are slowly replaced by concrete buildings. This could be a reason for Barn owl using mainly concrete structures in Kathmandu valley.

Though buildings are the most preferred site for Barn owls, the roost and nest sites in buildings were found either frequently occupied by Pigeons or sealed by humans due to their unwillingness to keep them in their buildings. The frightening screeches at night and remains of dead rodents around building were the reasons for their unwillingness. Nesting inside chimney and damaged roofs was problematic to the house owners which had to be sealed to avoid their nesting. This also caused the removal of occupied sites of Barn owl and required them to abandon the place forever. Due to inactiveness during day time (Falcon 2015), Barn owls are, outside their cavity, prone to attack by dogs and crows and also capture by human for fun and illegal trade.

5.3. Effects of LULC on occurrence of Barn owl

5.3.1. Plot level

The principle assumption of the study, that habitat attributes at multiple scales would influence the occurrence of Barn owl across different LULC features, has been met. The occurrence of Barn owl differed greatly between urban and rural area, with frequent occurrence in urban plots and the lowest in rural plots. The occurrence appeared to be consistent with the 'intermediate disturbance hypothesis' (Connell 1978) since the highest occurrence was found in sub-urban area, i.e. urban-fringe environment. The intermediate levels of urbanisation often record the highest level of avian species richness (Beissinger and Osborne 1982, Blair 1996, Clergeau et al. 1998). The reduction of vegetation density in suburban areas, the presence of residential gardens and urban features like streetlights increases prey availability and thus enhances foraging activity for the owl species (Weaving et al. 2011).

Modelling occupancy with LULC of Kathmandu valley suggested the tree cover as the explanatory variable for occupancy of Barn owl at plot-level with negative association, i.e. decrease in occupancy with increase in tree cover. The negative correlation of tree cover with Barn owl occurrence can be attributed to two factors: the Barn owl is closely associated with human settlements and is not a forest dwelling species (Mikkola 1983, de Bruijn 1994, Shawyer 1994, Cramp 1998). In addition, the absence of old-growth trees with suitable cavities as well as use of available trees by competitive species like Crows and Black kites may make trees unfavorable for Barn owl to roost and nest in Kathmandu valley.

There is little evidence that the occupancy of a plot is predicted by the grass cover which is consistent with the result of Hindmarch (2010). However, contradictory with her study in British Colombia, the association of grass cover is negative with Barn owl occupancy in Kathmandu valley. The differences in land cover, habitat composition, climate and elevation between British Colombia and Kathmandu valley, and the sample size and related factors could be the reasons for this contradiction. Kathmandu valley doesn't possess homogenous grass cover area; rather the existing grass covers are either fragmented into small patches, excessively disturbed by human activities or plotted for construction. The suitable habitats for Barn owl are severely limited in modern farmlands with a weak small-mammal population and thus limited prey availability

(Colvin 1985). In addition, expansion of farmlands for modern farming results destruction of wood- and grasslands neighboring the farm areas (Andersson 2015). This, in combination with the destruction and replacement of old, open farm houses with modern, closed buildings results in a drastic decline in nesting sites (Hindmarch et al. 2012). Also, the prey communities might not only be influenced by the amount of grass cover but also by the overall configuration of the landscape (Hindmarch 2010). Thus though Barn owl is grassland (Solymár and McCracken 2002) and farmland (Andrusiak 1994) related bird, several factors including the prey availability and nest site availability may be important in determining its occupancy.

There is positive correlation of presence of Barn owl with temple, built-up and road with the highest positive correlation with temples followed by built-up. The number of temples is concentrated and high in and around the heritage sites. These sites also have old settlements that provide structures suitable for perching, roosting and nesting for Barn owl. Temples are also considered as one of the best structures for Barn owl nesting (Neelanarayanan 2009, Ali and Santhanakrishnan 2012). The presence of pigeons around the temple sites may also provide them with prey species beside rodents (Gosai et al. 2012). Since Barn owls are closely related with human settlements (de Bruijn 1994, Shawyer 1994), the positive correlation with built-up can be explained. Roadsides provide favorable habitat (Briese and Smith 1974, Oxley et al. 1974, Abramsky 1978) and dispersal corridors for rodents (Getz et al. 1978) which could be the reason for positive association with occupancy of Barn owl at plot-level. Yet compared to other strongly supporting LULC features like temple and built-up, there is little evidence that the occurrence of Barn owl is influenced by the road length.

Though the tree cover is found to be strong candidate model among all models for prediction of Barn owl at plot-level, 12 other model combinations too show the support (ΔAIC = <2.0). The reason for number of supportive models could be due to complex heterogeneous landscape of the valley. Thus, at plot-level, large number of LULC attributes is found to show correlation with occurrence of Barn owl though the degree of association is different. They are also considered particularly sensitive to change and other minor factors in the habitat (Martinez and Zuberogoitia 2004) so pointing out one single factor as the general cause influencing its occurrence may be difficult. Considering the adverse impact of landscape features like intensive agricultural practices, and anthropogenic disturbances on breeding performances of Barn owl

(Almasi et al. 2015), further detailed study on supportive attributes for its survival across different LULC features of the valley is necessary. This may help to clearly understand if the current roost and nest sites and surrounding landscape features are positively influencing its breeding and survival or rather deteriorating.

5.3.2. Sub-plot level

The sub-plot level study area represents homogenous land cover features in most of the sub-plots since the area is small compared to the large plots. This assisted in evaluating the effect of LULC attributes on their occurrence, their preferred land feature within the small area and compare the result with the plot-level analysis.

Only four models received strong support. The modelling suggested the road length as the explanatory variable with negative association. Yet there was little evidence that the occurrence of Barn owl at site-level was influenced by road. The sub-plots covered less road lengths compared to the plots and these road lengths may not have significant impact for site-level occupancy.

Tree cover has the highest negative association in Barn owl occurrence at the sub-plot followed by grass cover which is similar to the result of plot-level study. Built-up area has strong positive relation to the site-level occupancy of Barn owl supporting the plot-level analysis and the fact that Barn owl mostly uses building structures for perching, roosting or nesting (Campbell and Campbell 1983, Shawyer 1987, Andrusiak 1994).

Multi-scale descriptions of the habitat preferences of the target species can produce meaningful results with regard to the response of animals to habitat loss in long run (Marchesi et al. 2002, Martínez et al. 2003). Thus, detailed information on rodent abundance in built-up areas and grass covers across the valley, at both landscape level and site-level, may help to evaluate how the type and configuration of built-up and farmlands influence the rodent populations. This in turn can help to clearly understand the occurrence and habitat use of Barn owl at the landscape and site-level, and help in formulating eco-friendly constructions as well as conservation plans and programs in the study area.

The Barn owl survey in Kathmandu valley, using call count method for an hour before and after sunset i.e. 1700 to 1900 hours, was found ineffective which could be due to very high (at 1700 hours) to moderately high (between 1800 and 1900 hours) traffic

(JICA 2012). The play-back call survey coincidence with high vehicular movement and heavy traffic may have negatively affected its effectiveness of play-back survey of Barn owls. Barn owls are adapted to hunt in silence, and spend most of their lives in silence (van Alphen 2013) which may be a reason for their passiveness to play-back call record. The best method to survey Barn owl was by searching for potential sites (Bunn et al. 1982, Shawyer 1987, Bibby et al. 1992) in coordination with locals during day time and monitoring the identified active sites at the evening usually after 17:00 hours. Employing local correspondents at different locations, by training them method of survey, was also an effective way to document Barn owl activities. This is widely adopted in UK for large scale Barn owl Monitoring Program (BOMP) by employing licensed volunteers (Leech et al 2009). Effective awareness on Barn owl importance to local people and empowering them as citizen scientists in research and conservation at local level with effective research protocols can be helpful for long-term conservation program for Barn owl and improve the urban ecosystem despite its complex LULC feature.

5.4. Post-earthquake scoping survey

The April 2015 Nepal earthquake of 7.8 moment magnitude (M_w) on 25 April 2015 and several major aftershocks e.g. 6.7 M_w on 26 April and 7.3 M_w on 12 May (NSC 2015) struck Nepal. Tens of thousands of buildings and structures collapsed in Kathmandu valley with severe impact on UNESCO World Heritages Sites and several temples (NDRRP 2015). The earthquake negatively affected most of the habitats of Barn owls and their activities. Temples and built-ups, especially old buildings and religious sites, are identified as the suitable habitats for their roosting and nesting by this study, and several other studies (Neelanarayanan 2009, Santhanakrishnan et al. 2010, 2011). These are the main structures severely damaged by the earthquake in Kathmandu valley (Goda et al. 2015, NDRRP 2015). This suggests the need to conserve remaining temples and heritage sites, construct the demolished ones and buildings or peripheral structures that can provide cavities and perching structures for Barn owls. Increased number of injured and stressed Barn owls, right after the earthquake, could be related to the impacts on their habitats or post-earthquake impact on other related LULC features including availability of prey densities.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This study presented baseline information on distribution of Barn owl in Kathmandu valley which was not studied scientifically till now. The study also identified LULC of the study area especially within sample plots. The effects of LULC on occurrence of Barn owl at plot level and site level were discussed. These effects when applied with management implications might help conserve ecologically important species of the valley.

The identified LULC of Kathmandu valley demonstrated that dense built-up was concentrated at the core of the valley with very less proportion of grass cover. The proportion of grass cover was high around the periphery of the valley.

The occurrence of Barn owl was found patchy and random with thin and scattered occurrence when moving towards the periphery of the valley. The concentration was high in mid-section of the valley extending from East to West which represented mostly urban-fringe environment.

The models revealed that the habitat attributes at multiple scales influenced the occurrence of Barn owl across different LULC features in the valley. Occupancy at plot-level was determined by tree cover with negative association which was similar to the sub-plot level study. The association was negative with grass cover at both levels. Positive association was found with temple and built-up. There was little evidence that the occurrence of Barn owl was influenced by roads and rivers.

The rapid urbanisation, especially conversion of old structures by concrete built-up without nesting/roosting cavities, and demolition of nesting sites by humans as well as natural calamities like earthquake seems threat to the continuity of Barn owl population in Kathmandu valley.

6.2. Recommendations

The following is a list of major recommendations for the management and conservation of Barn owl in the Kathmandu valley based on the results of this study.

- Research should be conducted on diet, reproduction, breeding success, prey abundance and rodent population status along with nest site availability across different LULC in Kathmandu valley to clearly understand the status of Barn owl, its suitable habitat and attributes supportive for its survival in the valley.

- The local people, particularly of Barn owl priority area i.e. plot P39, P41 and P47 (Kirtipur Municipality, Lalitpur Municipality and Bhaktapur Municipality) identified by this study, should be given awareness about the importance of Barn owl in their locality and local environment. They should be encouraged to protect the existing roost and nest sites, if required install Barn owl nest boxes and discourage activities of destroying their habitat or capturing them for fun or trade. Research and monitoring should be done to check the utilization of installed nest boxes and its effectiveness in the valley.

- Monitoring of Barn owl occurrence and population status should be continued with wide participation of locals as citizen scientists and replicate the study in areas untouched by this study.

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APPENDICES

1. Locations included by the sample plots in Kathmandu valley.

Plot code	VDCs/Municipalities	District
P4		
	Dharmasthali	Kathmandu
	Goldhunga	Kathmandu
	Manmaiju	Kathmandu
	Futung	Kathmandu
	Kathmandu Metropolitan City	Kathmandu
	Kabhresthali	Kathmandu
P8		
	Budanilkhantha	Kathmandu
	Tokha Saraswathi	Kathmandu
	Tokha Chandeswori	Kathmandu
	Dhapasi	Kathmandu
	Mahankal	Kathmandu
	Kathmandu Metropolitan City	Kathmandu
P8		
	Chunkhel	Kathmandu
	Baluwa	Kathmandu
	Kapan	Kathmandu
	Gokarneswor	Kathmandu
	Nayapati	Kathmandu
P18		
	Ichangu Narayan	Kathmandu
	Sitapaila	Kathmandu
	Kathmandu Metropolitan City	Kathmandu
	Ramkot	Kathmandu
P20		
	Kathmandu Metropolitan City	Kathmandu

P22		
	Kathmandu Metropolitan City	Kathmandu
	Jorpati	Kathmandu
	Gothatar	Kathmandu
P24		
	Daanchhi	Kathmandu
	Gokarneswor	Kathmandu
	Jorpati	Kathmandu
	Mulpani	Kathmandu
	Duwakot	Bhaktapur
	Changunarayan	Bhaktapur
P39		
	Naikap	Kathmandu
	Satungal	Kathmandu
	Tinthana	Kathmandu
	Machhegaun	Kathmandu
	Kirtipur Municipality	Kathmandu
P41		
	Kirtipur Municipality	Kathmandu
	Kathmandu Metropolitan City	Kathmandu
	Lalitpur Sub-metropolitan City	Lalitpur
P42		
	Kathmandu Municipality	Kathmandu
	Madhyapur Thimi Municipality	Bhaktapur
	Lalitpur Sub-metropolitan City	Lalitpur
	Imadol	Lalitpur
P43		
	Madhyapur Thimi Municipality	Bhaktapur
	Gothatar	Kathmandu
	Balkot	Bhaktapur
	Duwakot	Bhaktapur
P47		

	Duwakot	Bhaktapur
	Jhaukhel	Bhaktapur
	Bhaktapur Municipality	Bhaktapur
P65		
	Kirtipur Municipality	Lalitpur
	Chalnakhel	Lalitpur
	Khokana	Lalitpur
P67		
	Lalitpur Sub-metropolitan City	Lalitpur
	Sainbu	Lalitpur
	Sunakothi	Lalitpur
	Dhapakhel	Lalitpur
	Harisiddhi	Lalitpur
	Imadol	Lalitpur
P69		
	Tikathali	Lalitpur
	Sidhipur	Lalitpur
	Lubu	Lalitpur
	Sirutar	Lalitpur
P79		
	Bungamati	Lalitpur
	Satikhel	Lalitpur
	Dukuchhap	Lalitpur
	Champi	Lalitpur
	Thecho	Lalitpur
	Chapagaun	Lalitpur
P81		
	Thaiba	Lalitpur
	Jharuwarasi	Lalitpur
	Chapagaun	Lalitpur
	Badikhel	Lalitpur
	Godawari	Lalitpur

2. Nest Site definitions according to Barn Owl Survey Methodology and Techniques by Shawyer (2011).

S.N.	Nest Site	Description
1	Potential Nest Site (PNS)	agricultural or old industrial buildings with suitable access and possessing an upper floor, loft, roof void, blocked chimney, wide wall plate, bale-stack, empty water tank, ducting or large nest box;
		disused or derelict cottages or industrial buildings such as aircraft hangers, which possess an open joist, broken ceiling panel, water tank, disused chimney or large nest box;
		mature trees, isolated or in clusters in open fields, hedgerow or on the woodland edge, containing a hole >80 mm backed by a large, dark cavity, including those which have rotted-out to ground level but which offer no obvious access to ground predators through an open root structure;
		outdoor nest boxes on poles, trees, buildings or owl towers, which offer a dark chamber;
		waterway, rail or road bridges containing suitable cavities within their structure; and
		churches, mainly rural, and the chimneys of intermittently-used holiday homes.
2	Active Roost Site (ARS)	place where the bird is seen or heard regularly or its current or recent presence (last 12 months) can be recognized by signs of thick, chalky -white, streaky droppings accompanied by regurgitated pellets and moulted feathers;
		old buildings, trees or rock , sometimes quite close to the ground and often in open-fronted buildings that are well lit, commonly on a beam, length of upright timber leaning against an interior wall, fence post, exposed tree branches;
3	Temporary Rest Site (TRS)	Small spots of thick, chalky cream-colored droppings that can often be seen underneath a tree, in a building or on a fence post and which are sometimes accompanied by an occasional pellet or body feather;
4	Occupied Breeding Site (OBS)	one where breeding was taking place or where it had done so in the recent past;
		Presence of adult Barn owls, their moulted feathers, pellets, eggs, egg shells, chicks or down;

3. LULC variables for mapping and statistical modelling to examine occupancy of Barn owl at site-level.

Variables	Code	Description
Built-up (%)	BUILT	Percentage of impervious surfaces; rooftops, parking lots, highways and streets, vehicles, green house and commercial concrete areas
Grass cover (%)	GRASS	Percentage of grasslands, farm and fallow lands, set asides, notable grass verges, open grounds
Tree cover (%)	TREE	Percentage of tree patches, forest area
Water (%)	WATER	Percentage of water bodies
Roads (km)	ROAD	Length of major roads
River (km)	RIVER	Length of rivers
Temples	TEMPLE	Number of temples

4. LULC variables for mapping and statistical modelling to examine occupancy of Barn owl at site-level.

Variables	Code	Description
Built-up (km^2)	BUILT	All residential, industrial, greenhouses and commercial lands; rooftops, parking lots, highways and streets, vehicles, green house and concrete areas.
Grass cover (km^2)	GRASS	Grasslands, farm and fallow lands, set asides, notable grass verges, open grounds
Tree cover (km^2)	TREE	Tree patches, forest area
Water body (km^2)	WATER	Water body area
Roads (km)	ROAD	Length of major roads
River (km)	RIVER	Length of rivers

5. Land Use and Land Cover attributes of survey plots

Plot	Water body	Tree cover	Built up	Grass	Road length	River length	Temple number
P4	0.388	6.109	39.195	54.308	3.424	8.970	2.198
P6	0.071	5.544	36.405	57.980	1.958	5.836	2.198
P8	0.000	25.573	4.056	70.370	0.000	4.500	0.000
P18	0.000	5.941	73.126	20.934	8.595	0.714	5.495
P20	0.564	6.138	82.751	10.547	16.143	1.627	12.088
P22	0.847	3.036	74.585	21.532	6.387	4.433	7.692
P24	0.496	11.269	20.198	68.037	5.442	6.056	0.000
P39	0.282	2.149	36.914	60.655	6.072	9.431	6.593
P41	1.939	3.879	79.549	14.633	16.191	6.400	23.077
P43	2.793	0.035	76.670	20.502	9.000	9.131	2.198
P45	0.212	0.882	42.837	56.069	6.099	3.506	4.396
P47	0.494	1.341	35.086	63.078	4.103	4.849	21.978
P65	2.294	13.131	8.648	75.927	2.835	6.031	2.198
P67	0.636	2.472	43.856	53.037	5.553	4.182	1.099
P69	0.424	1.096	23.294	75.186	3.748	7.141	5.495
P79	1.344	11.143	7.216	80.297	2.984	5.819	1.099
P81	0.177	9.933	15.942	73.948	1.465	11.373	2.198

6. Land Use and Land Cover attributes of sub-plots.

Plot	Site	Area of (m^2)				Length of (m)	
		Built	Grass	Tree	Water	major roads	major rivers
P4	4a	57016	115608	20593	2809	670	638
	4b	61446	130726	3816	0	2070	0
	4c	80276	101345	14308	0	1382	0
	4d	121288	68865	0	5929	670	495
P6	6a	9902	141624	44520	0	797	0
	6b	96032	85668	14432	0	70	0
	6c	37269	138309	20591	0	358	0
	6d	111007	65059	24684	0	528	0
P8	8a	0	48442	147766	0	2098	0
	8b	6906	134472	54597	0	2079	672
	8c	17216	162796	15082	1067	1028	199
	8d	9189	162644	24282	0	1162	0
P18	18a	148318	47839	0	0	482	0
	18b	116183	80040	0	0	18	0
	18c	117094	34510	45998	0	753	0
	18d	149229	45331	1653	0	232	0
P20	20a	191226	4986	0	0	67	0
	20b	179045	4859	12185	0	0	0
	20c	160515	24205	11323	0	249	0
	20d	164698	16462	15000	0	70	0
P22	22a	185255	8372	2587	0	153	0
	22b	188553	4833	2834	0	70	0
	22c	83520	103552	0	9057	70	536
	22d	54263	128585	6850	6445	100	483
P24	24a	25031	136227	34841	0	225	0
	24b	18267	177017	742	0	468	0
	24c	6422	182933	6772	0	1441	520
	24d	32076	160913	3199	0	893	0

P39	39a	98515	87578	6731	3389	105	674
	39b	123335	53100	17387	2290	320	607
	39c	37598	158569	0	0	336	0
	39d	7042	187210	1972	0	1109	0
P41	41a	167406	19213	0	9572	98	413
	41b	180759	7631	7758	0	528	0
	41c	166847	12819	16404	0	333	0
	41d	173984	22213	0	0	54	0
P43	43a	183389	10065	0	2758	100	394
	43b	55267	140940	0	0	219	0
	43c	110620	84462	1096	0	166	0
	43d	187021	8734	475	0	250	0
P45	45a	46623	143481	6101	0	413	0
	45b	17004	179210	0	0	487	0
	45c	14296	181918	0	0	343	0
	45d	55269	134261	6681	0	435	0
P47	47a	15964	180260	0		1250	0
	47b	18684	171725	5801	0	1113	0
	47c	89818	106327	0	0	169	315
	47d	38983	157193	0	0	249	483
P65	65a	30140	106272	20813	38971	122	0
	65b	0	196218	0	0	587	0
	65c	0	196247	0	0	1132	0
	65d	1253	169050	25837	0	250	0
P67	67a	121884	74289	0	0	125	0
	67b	70652	96254	29266	0	26	0
	67c	27174	167294	1749	0	600	218
	67d	51962	144217	0	0	378	
P69	69a	25400	170757	0	0	100	132
	69b	9011	187175	0	0	564	0
	69c	54462	140545	1187	0	182	0
	69d	19411	165225	9236	2331	756	540

P79	79a	180341	15886	0	0	1679	0
	79b	0	190165	5961	0	674	587
	79c	0	185347	10863	0	981	0
	79d	0	187427	8725	0	1930	0
P81	81a	10416	138545	47238	0	1071	0
	81b	9759	183143	3324	0	265	225
	81c	22078	156738	17394	0	772	233
	81d	6597	185692	3879	0	1604	681

PHOTOPLATES

a. Temporary Rest Sites and Active Roost Sites of Barn owl in Kathmandu valley

b. Occupied Breeding Sites of Barn owl in Kathmandu valley

a. Threats to Barn owl; cracked and demolished old houses, illegal capturing, mobbing by crows and inter-species competition with pigeons for roosting and nesting sites

c. Death of Barn owl at different locations in Kathmandu valley

d. Rescue of stressed and injured Barn owls from different locations of Kathmandu valley

e. Interaction with locals and survey of indirect signs of Barn owl