# SPATIAL ANALYSIS ON RELATIONSHIP BETWEEN WILDLIFE-HUMAN CONFLICTS IN SENAI-DESARU EXPRESSWAY (SDE) IN 2009-2015

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**ABSTRACT:** Malaysia has one of the richest biodiversity and extensive road networks throughout the country. One of the consequences emerges from this condition is wildlife-vehicle collisions (WVC), representing a remarkable non-natural death in wildlife species. Hence, the knowledge and deliberation of gap analysis on Human-Wildlife Conflict (HWC) is indispensable to convalesce and recuperate the safe co-existence between animal populations and human needs including transportation of people or goods along the expressway. This study is to (a) evaluate the landuse patterns on the distribution of HWC, (b) assess whether HWCs are clustered forming mortality hotspots along 70km of Senai-Desaru Expressway (SDE). Annual recorded data of HWC s from 2009-2015 was collected, involving mammal at various size while Landsat satellite images used to detect land-use changes at both sides of SDE. Several environmental variables including human-wildlife conflict trend, signifying suitability of wildlife habitat and landscape connectivity, while accounting for spatial effects. More than 30 trapping camera were set-up at both sides of SDE to identify hotspots of HWC and to support the result such as species of animal killed, land-use type, sloppiness of terrain relief and logistic facilities which could stimulate the WVCs. Based on the result, WVC and landuse type demonstrated a strong relationship for all existing species that could explained the annual trend. Tree cover, distance to riparian areas, terrain ruggedness and poor unmaintained fencing system along SDE were important stimulator of WVCs. Seven main hotspots of mortality was detected along SDE in 2015, yet only one road section ($20^{th}$ -$30^{th}$ km) was classified as hotspot for more than 35 number of WVC. From 2009, the number of WVCs at some sections are decreased indicates the adaptability of wildlife to new invented habitats and effectiveness of mitigating action but fluctuating trend is shown in remaining section. To conclude, WVC mainly occur in road sections with more abundant and diverse wildlife communities. Mortality hotspots definitely provide significant information for mitigation in selected prioritized road sections. The results support focusing on hotspots, habitat quality and landscape connectivity for a better assessment of road mortality. At the local scale, road passages with regular maintenance of exclusionary fencing and appropriate mesh size in riparian areas may provide safe crossings for many species and constitute a promising mitigation measure.

## 1. INTRODUCTION

Road infrastructure is expanding in developed and developing countries as increasing number of vehicles on road and people become more accessible to many destinations within a short time. Meanwhile, the opening of new territories for urbanization has brought the impact on distribution of residential area and biodiversity balance. In low-income countries, disproportionate biodiversity loss was occurred and it highly associated with the expanding resource use of developed countries (WWF, 2014).

Roads can create fragmentation of wildlife habitat patches which leads to limitation of their areal movement and unstable inter-relationship between human and wildlife demand. Restriction on movement space for medium to large wildlife directly leads functional isolation of population (Vos and Chardon, 1998) and increase pressure of reduction in habitat quality. In fact, tropical countries such as Malaysia have high vegetation density and prolonged light intensity that influence the spatial pattern of wildlife movement due to natural wide-ranging behavior, seeking for food and

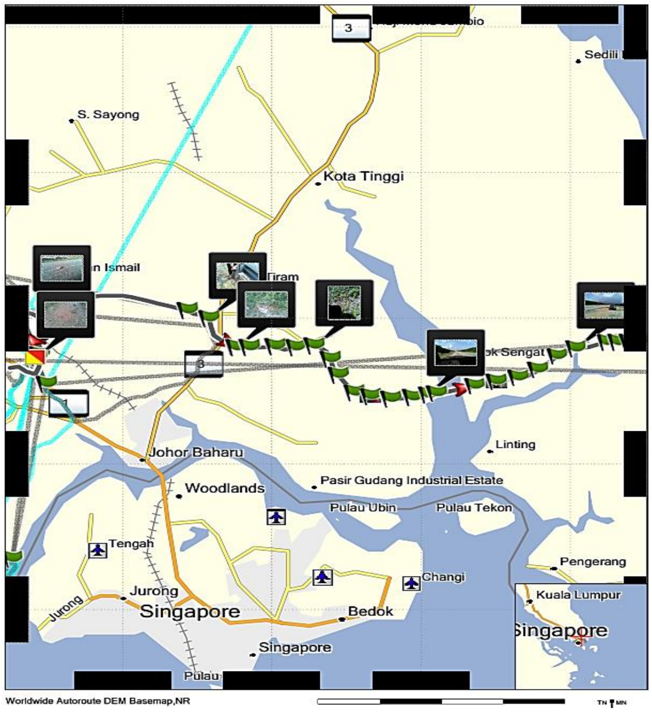
partner shelter. Indirectly, these situations may result to human-wildlife conflicts where new roads become frequent land-space for unexpected collisions between animal and vehicle. Road-kill frequency increases with higher traffic speeds, particularly on paved roads (Drews, 2008; Smith-Patten and Patten, 2008 and Collinson, 2013) and high traffic volume often acts as a barrier for wildlife (Seiler, 2003).
The distribution of human-wildlife conflict is, however, heterogeneous and spatial analysis on relationship between wildlife-human conflicts and other characteristics in Senai-Desaru Expressway (SDE) is still uncertain. The understanding of that spatial relationship is critically indispensable to improve and recuperate the safe coexistence to answer demand of human and wildlife survival as large mammals has growth rate and low reproductive rates. In this study, identification of mortality hotspots could be spatially analyzed to construct efficient mitigation measures to reduce HWC rate along SDE. In fact, species identification that most frequently involved in conflict with human could be effectively used in mitigating certain road segments and improving fencing infrastructure at critical spots along the roadside.

## 2. METHODOLOGY

Nowadays, scientists are working to optimally reduce HWCs in rural area by connecting mobile phone to animal movement using tracking tools and remote cameras. This approach offers species monitoring at high resolution. Using ground-based approach, scientists normally optimized the synergy between remote-sensing satellites, smartphones, Geographical Information System (GIS) and related communication gadgets. Collected real-time data are transferred through the network of mobile phone or satellite constellation. All collected data reveal the movement patterns while high-resolution satellite imagery used to understand observed animal behavior. In fact, GIS tools have capability to develop land use risk maps and integrate them in an online mapping tool to help guide sustainable agricultural development for local people (Hower, 2015). This approach is applicable for small area where the cost is sufficient enough to conduct such study and ample of time and expertise. In this study, satellite-based approach is used to cover relatively huge area along SDE using information collected from: a) camera trap of every 2km in SDE to identify animal species at SDE roadside, b) landuse classification from multi-temporal satellite image in 2009 and 2015 while landuse of 2002 and 2012 is digitized data from related government agency; c) handheld GPS Montana 650 used to record location of camera trap, type of landuse and continuous elevation estimated by GPS system following car movement along 70km of SDE; and d) elevation from Digital Elevation Model (DEM) of area of interest. This information would be integrated with information collected from SDE's authority including date of any WVC from 2009 to 2015, location, species of animal involved, annual amount of WVCs and spatial analysis of all information gathered.
In this study, HWC will be grouped into two types of animal, livestock (LS) and wildlife (WL). However, wildlife will be used in previous section for easy understanding to depict situation of all animal from both groups. SDE has been covered with different types of land-use and land-cover at hilly and flat terrain surfaces along 70km right and left side. Therefore, DEM and Landsat ETM+ of 2009 and 2015 were processed to attain land-use changes using supervised classification technique. Detailed processing steps can be referred to typical image processing procedures such as pre-processing and processing stage including geometric correction, atmospheric correction, digital number to radiance conversion, image subset, image masking and accuracy assessment (Misbari; 2013). All digital processing procedures and extracting information are accomplished using ENVI 5 and ArcMap processing system. The analysis of the result is more focused on the several important factors that highly contribute to increasing trend of wildlife-human conflicts along the road.

### 2.1 Study Area

Located in west to east part of Johor, SDE or namely SDE E22 is a new tolled 77km-expressway in Johor, Malaysia to improve road infrastructure of the resident who wish to make a high-speed journey from Senai at west to east part of Johor, Desaru. Known as the longest single plane cable stayed bridge in Malaysia, 1.7km of SDE Bridge across Johor River in west part now becomes an important landmark in Iskandar Region, Johor. It involves the construction of 4 toll plazas, 2 Rest & Service Areas, 6 interchanges, 1 intersection and SDE Bridge. Currently, SDE is the main access road to Desaru and the main alternative road to Senai International Airport for people live in eastern parts of Johor. SDE traverses through Sultan Iskandar Reservoir, the environmentally sensitive water catchment area. Along the roadside of SDE is comprises of several landuse types such as oil palm area, mangrove forest, residential area and poultry farm. Introduction of Pollutant Removal System (PRS) in SDE is an effective approach to detect and manage a spillage of dangerous and hazardous chemicals from any vehicle travelling on the expressway.




(a) (b)

Figure 1. (a) Location of trapping camera (green flag) at both side of SDE; and (b) Aerial view of SDE's landmark, a 1.7 km cable-stayed bridge across Sungai Johor. (Source: http://www.pbase.com/bmcmorrow/aerialsasia)

## 3. RESULTS & DISCUSSION

The spatial analysis and discussion of the HWCs trend and result in this study is focused on several aspects, including (a) HWCs relative to landuse type; (b) HWCs with relation to types of animal involved; and (c) identification of hotspot of HWCs by sectioning SDE into 10km interval. Geographical information system (GIS) is an important technology to investigate a wide range of problems by conservation biologists and related expertise. In this study, GIS and remote sensing is applied to analysis of HWC data. The result shows that this approach has great potential for understanding HWC in SDE and next section will discuss in detail on this aspect.

All recorded animal by trapping camera shows different size of animal from medium to large mammal or reptile such as wild boar, monkey, snake, squirrel, bird, monitor lizard, cow and stray dog. It shows high probability of these animal species exposed to WVCs in SDE. Casualties recorded by SDE authority involving at least six species including wild boar, monkey, cow and stray dog. Yet, none of them categorized under endangered species since SDE area is far from permanent forest. Similar to previous studies, results of WVC in SDE shows that medium to large animals present therein were affected (Caceres, 2008) while small size of animal is not easily involved in dramatic road accidents.

### 3.1 HWCs relative to landuse type

Conflict between human and wildlife demands can be understood by analysing the trend and pattern of all spatial distribution of roadkill locations in SDE with surrounding landuse type. Common aggregation pattern found in WVC data in SDE and spatial analysis measures proved the fact that HWC mainly occur in road sections traversing areas with more abundant and diverse communities (D'Amico, 2015). It is common that many animal species do not show road avoidance (Jaeger, 2005) and it shown by animal involved in HWC in SDE. Thus, it is conceivable that a large abundance will lead to high rate of casualties of a certain species in SDE, particularly monkey, wild boar and stray dog.

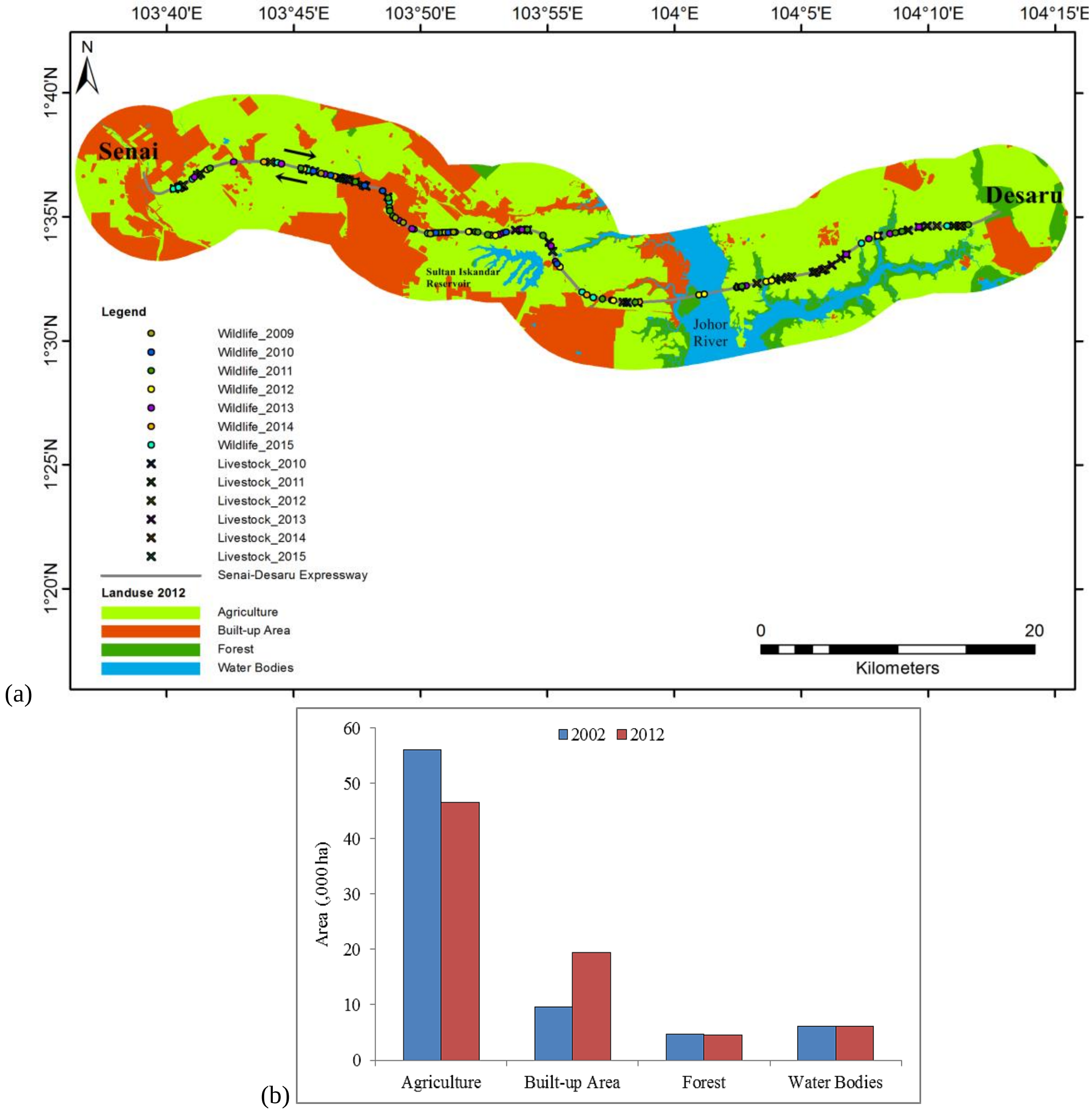



Figure 2. (a) Location of HWCs in 2009-2015 and 10km buffer zone shows various type of landuse 2012 at both sides of the road; and (b) landuse changes between 2002 and 2012

Based on Figure 2(a), agriculture (light green) is dominant landuse type at side of SDE, followed by built-up area (orange) which highly dense at roadside of Desaru-Senai direction. Agriculture is the result of landuse conversion from natural forestry or bushes to commercial plantation area where previously it was a playing ground area of wildlife for food hunting and shelter. Statistic of WVC recorded by SDE authority, it has strong correlation between number of WVCs with landuse type, especially for some wildlife species that normally inhabits agricultural area. In fact, Sultan Iskandar Reservoir with area of 5km (length) x 2km (width) is the attraction for wildlife to cross the road for water resources, indicated by highest number of HWCs on its adjacency closed to this location. Moreover, built-up area nearby the man-made reservoir is consists of many residential areas that increase the pressure for wildlife to quickly adapt with such environment and become disturbance to their mobility and survival. Figure 2(b) shows landuse changes of processed-Landsat image of 2002 and 2012. Obviously, class of 'built-up area' shows very significant increment from only 9670.4 ha in 2002 to 19480.4 ha, increased about 101.4 % whereas water bodies are consistent and slight decrement of agriculture and fragmented forest area is recorded. This situation shows the combination of rising human intervention on wildlife habitat and decreasing of their movement area that catalyst HWCs to occur at both side of SDE. By associating HWC with landuse type, it is strongly believed that landscape connectivity and resource distribution for different species gives significant impact on HWC rate (Santos, 2013).

### 3.2 HWCs according to different animal category

SDE is mostly surrounded by greenish space where mangrove forest, agriculture, oil palm area and bushes along SDE at both side is unified to form various landuse type. To compare, animal found involved in HWC in SDE (urban area) is almost similar to peripheral area by referring to related studies conducted by Hashim et al., 2014. Inter-relationship bonding in terms of ecological service and natural symbiosis between all landuse types has brought significant impact on the wildlife mobility and thus rate of annual casualty. Since there is no wildlife bridge that connects right and left side of the road, wildlife animal would likely to cross the road looking for their needs such as food, water, partner and suitable shelter. Livestock such as a group of cow can be seen at certain grassy land along both roadside of SDE during the journey from Senai to Desaru and vice versa. Compared to wildlife, the number is comparatively lower but the size is relatively larger than other wildlife. From this perspective, it can be understood that there is random hole at certain location along the SDE that allows large animal such as cow and wildboar successfully escape from the greenish space into the road zone causing collisions with speed vehicle, especially during night. The record given by authority did not state the time of WVC occurrences, thus analysis on this part, especially for nocturnal animal is not possibly done.

Table 1. Number of HWC in SDE from 2009 to 2015

| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|
| Livestock | 0 | 7 | 15 | 13 | 10 | 5 | 6 | 56 |
| Wildlife | 5 | 8 | 26 | 17 | 23 | 13 | 17 | 109 |
| Sum | 5 | 15 | 41 | 30 | 33 | 18 | 23 | 165 |
| Annual rate ($km^{-1}$) | 0.06 | 0.19 | 0.53 | 0.39 | 0.43 | 0.23 | 0.30 | |

The overall HWC incident density in SDE from 2009 to 2015 is fluctuated over years but the statistic shows the concentrated WVC is at the third section of SDE in 2011 where the rate is was 0.53 incidents $km^{-2}$ $year^{-1}$. In the earlier stage of opening, HWC rate along SDE is comparatively lowest where only 0.06 $km^{-2}$ $year^{-1.}$ This trend slightly increases in coming years and reach its climax in 2011 as shown in Figure 3. These results seem generally high for SDE considering the total of its length is relatively much shorter than other expressway in Malaysia. In 2009, no livestock involved in any collisions with vehicle in SDE, possibly due to new fencing set-up along SDE and less volume of traffic. However, the number is increasing in the following years indicate there is expansion of farming activity at SDE roadside. Peak of wildlife collision reached its peak in 2011 for both livestock and wildlife type. Referred to Figure 2(a), many livestock accidentally died in east part of SDE, area of Desaru where the oil palm plantation is dominant at both sides. In 2012 and forwards, livestock number involved in HWCs is decreasing. In contrast, the number of wildlife involved in HWCs is fluctuated after 2011, indicates inconsistent main causal factor that significantly affects the wildlife collision with vehicles in SDE. After 2011, overall total number of WVC does not shows any significant pattern but relatively the amount is lower than 2011 but slightly higher than 2009 and 2010. New facilities and mitigation action taken by SDE authority could bring impacts on the HWC's statistic in SDE over years.

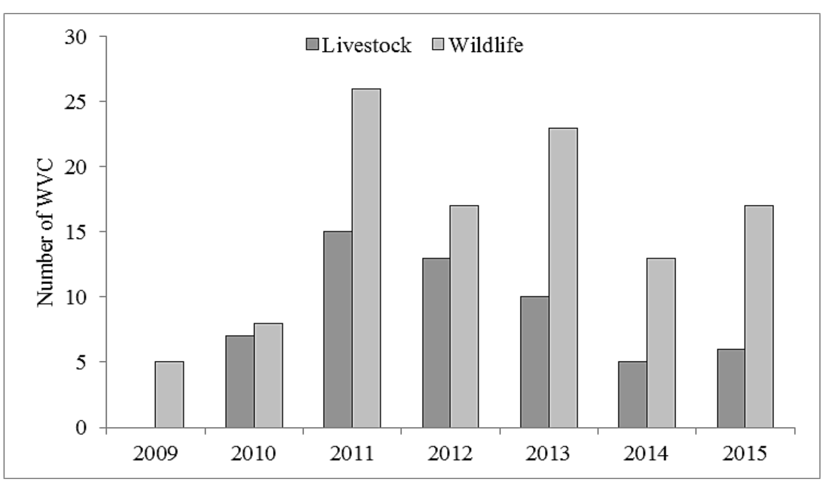



Figure 3. Trend of WVC in SDE between livestock and wildlife.

### 3.3 Identification of hotspot of HWCs in SDE

Figure 4 illustrates levels of HWC incident density. However, it preferable to identify areas which have higher incident levels than expected, given the influence of another factor. SDE was divided into 7 sections which every section has 10km length to efficiently identified which section is the most susceptible to HWC that can be used for mitigation plan and improve SDE management of infrastructure for long term maintenance.

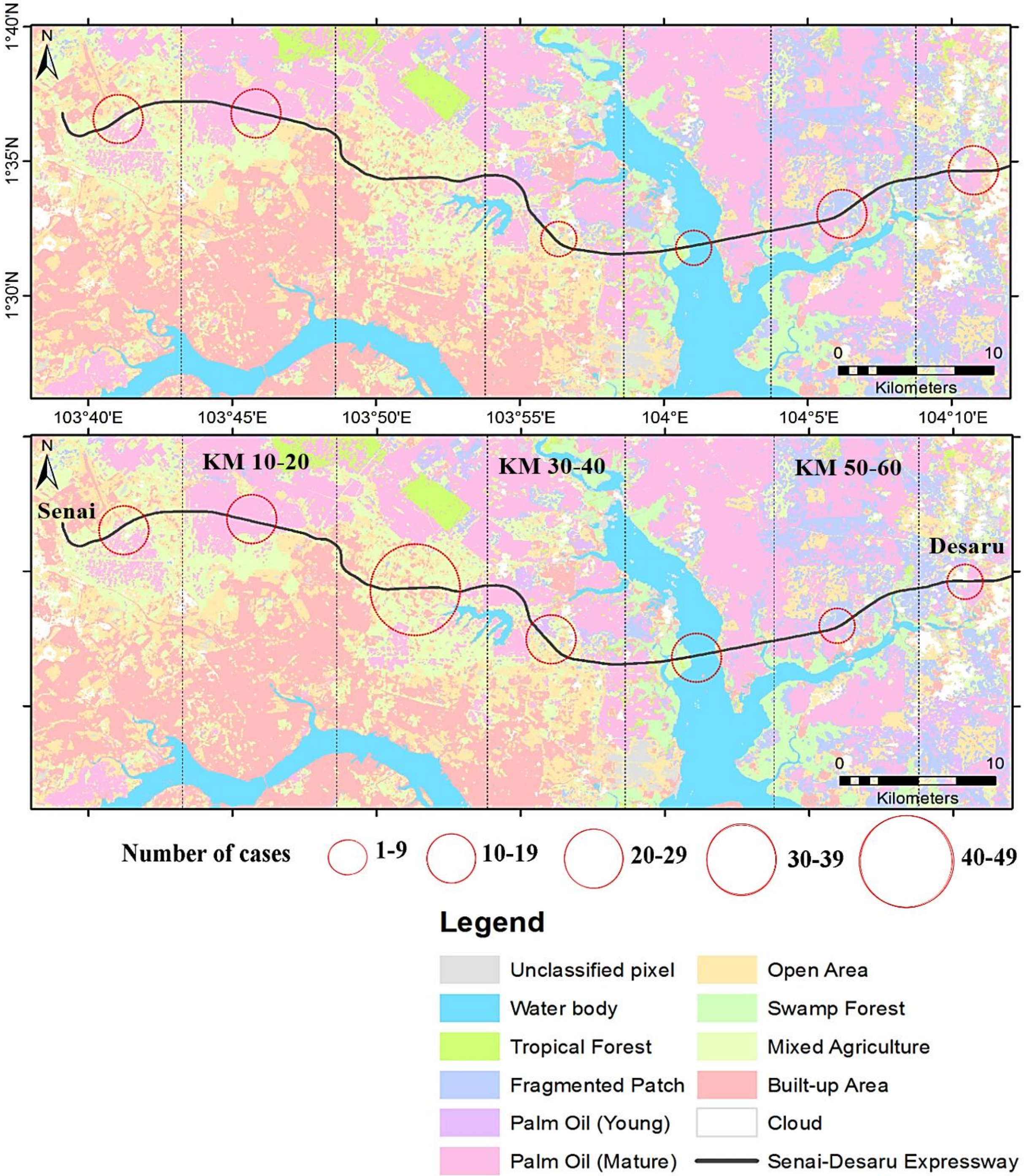



Figure 4. Upper part shows HWC cases in 2009 and lower part is HWC cases in 2015 based on different road section (10km interval) in SDE. Type of landuse presented is the result of supervised classification on Landsat image of 2009 and 2015.

Several hotspots in all section were detected in SDE that are good candidates for mitigation measures to be applied. Based on Figure 4, highest number of HWCs in SDE had occurred in 2011 in KM 20$^{th}$-30$^{th}$ and relatively higher every year compared to other section. Poor unmaintained fencing system primarily at hotspot area of KM 20$^{th}$-30$^{th}$ after two years of SDE's opening and increasing traffic intensity by rising number of vehicles on SDE are probably the main reason the peak season of HWCs throughout 2011, especially for wildlife animal because no livestock was reported in 2011 involved in such accidents. In fact, Sultan Iskandar Reservoir attracted many animal and nearby residence to compete for water source. Moreover, elevation at this area shows terrain relief is higher than other sections as shown in Figure 5, triggering HWCs to occur due to high speed of vehicles at declivitous road at both sides of the steep road, primarily when any large wildlife cross the road at night or wet season. Billowy surface or non-flatted road in SDE influence the vehicle speed where road user naturally drive at higher speed than flat surface. In addition, the road network is expanding, further reinforcing probability of the negative consequences for wildlife. Broad-scale management should targets areas of high conflict between road networks and wildlife (Laurance and Balmford, 2013) to preserve Malaysian biodiversity.

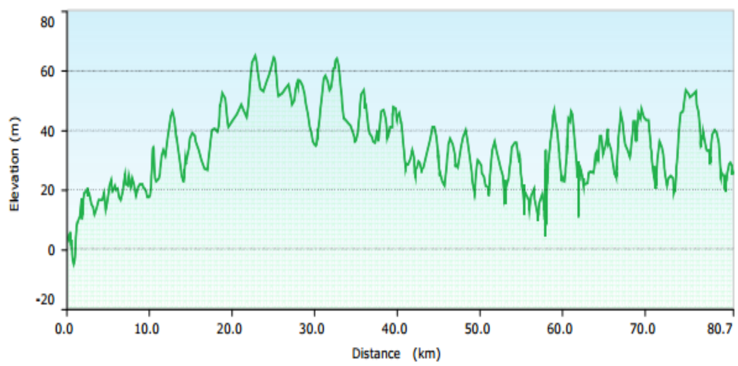



Figure 5. Elevation of terrain surface in direction of Senai to Desaru.

The increasing volume of traffic on SDE was one of the factors stimulate HWCs to frequently occur. Desaru serves magnificent views of coastal and become popular destination in festive season for family vacation is one of the prime reasons of increasing HWCs number in SDE. In normal days, less number of vehicles reduces the probability of HWC to occur. In terms of animal behavior, animals are quickly responses when the vehicle was at lower speed, where the distance is shorter. In this condition, it could be suggested that higher vehicle speed can increase potential HWCs, mainly area close to reservoir in SDE because wildlife is very attracted to areas where water and food is available.

Table 2. Statistic of HWC at both directions of SDE; Senai-Desaru (S-D) and Desaru-Senai (D-S) according to four different landuse types.

| **Year** | **Agriculture** | | **Built-up area** | | **Forest** | | **Water body** | |
|---|---|---|---|---|---|---|---|---|
| | **S-D** | **D-S** | **S-D** | **D-S** | **S-D** | **D-S** | **S-D** | **D-S** |
| 2009 | 4 | 4 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2010 | 10 | 9 | 5 | 6 | 0 | 0 | 0 | 0 |
| 2011 | 37 | 37 | 4 | 4 | 0 | 0 | 0 | 0 |
| 2012 | 21 | 20 | 4 | 5 | 4 | 4 | 1 | 1 |
| 2013 | 28 | 30 | 2 | 1 | 2 | 1 | 0 | 0 |
| 2014 | 15 | 14 | 2 | 1 | 0 | 0 | 0 | 2 |
| 2015 | 19 | 18 | 3 | 5 | 1 | 0 | 0 | 0 |
| Sum | 134 | 132 | 21 | 23 | 7 | 5 | 1 | 3 |

Table 2 shows that WVC was most frequently occur in agricultural area in S-D direction, particularly in 2011 and remain high until 2013. In fact, statistic of D-S direction also showed highest WVC compared to other three landuse type. It is because agricultural area is main location for food source and it is dominant in most area of SDE's roadside that easily exposing wildlife to roadkill accident. The spatial analysis of HWC data in SDE identifies which factors have a major impact on the observed conflict trend. These factors are directly determined where HWC incidents occurred but they may act instead as a surrogate for other unmeasured factors. This analysis found that HWC incident density in section in SDE was significantly related to the road distance from permanent water, human-populated area and road elevation. Therefore, HWC density was highest in section that was close to water, residential area with poor fencing condition at both roadside and declivitous road area. Other correlations may also important such as correlation between distance of road to permanent water, wildlife density, residential population and vegetation covers. All these four factors influence the HWC levels. Similarly, inconsistent elevation in each section was associated with slope where its significance is partially dependent on its correlation with the other environmental component including weather, landuse and public infrastructure provided on the road such as light reflector or road divider.

Among all significant factors, distance of SDE to water directly influences the patterns of HWC wherever human and wildlife are compete for resources. In contrast, HWC is low wherever successful mitigation measures like maintained fencing system are being practised. It is found that wildlife in SDE is not avoiding steep and high ground when moving across the district. Thus, HWC incidents continue to occur in various locations and non-permanent migration route, even when there are no crops present and surface water is freely available.

This study offers good information for prompt road planners for installing mitigation measures in more vulnerable area along expressway during the planning phase. This is crucial in regions like Malaysia that highly rich with biodiversity and has one of the most excellent road infrastructures in the world. In future, it is advisable that these explanations and questionable matter could be studied by movement tracking of livestock and wildlife using GPS radio collars (Douglas-Hamilton, 1998). This would allow data record on the nocturnal movements of these animals but this method is expensive. However, such a study would be very valuable and beneficial for long-term goal. Moreover, constructing a longer fence would ultimately reduce HWC although longer fence would be costly. Suggestion on relocating these people or offer an alternative source of income would be an intricate process. As mitigation advice, it is a great invention if the management of SDE could build a wildlife crossing bridge, as have been practised in many developed countries like Singapore. Using GIS technology, this bridge would benefit greatly that could incorporate all the available information. In addition, the usage of fencing method is suitable at some road sections to delineate road and roadside area, focus to avoid animals deviating from these routes and people living in neighbouring areas should be careful while driving. Although simple procedure used to evaluate the cross-species benefit of mitigation, identified hotspots in SDE may have a limited overlap across species and so mitigation focussed on the WVC of certain problematic species may have limited benefit for other species (Clevenger and Waltho, 2005). Thus, despite being important tools to prioritise road sections for mitigation, the identification of HWC hotspots might omit other species and records of WVC.

## 4. CONCLUSION

In conclusion, HWC incident density is highest in 2011, influenced by landuse type at both roadside, fencing system, increasing traffic volume and terrain surface of SDE. Spatial analysis and satellite-based application could effectively extract valuable information which is useful for management tool. Balance of state strategic development and great endeavor to meet demand between human needs and wildlife surviving factors should successfully reduce statistic number of HWC in SDE. Hence, our results reinforced the need for management actions as suggested to reduce the number of WVCs in study area.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