

Abstract

Nonnative species are disruptive to natural ecosystems. The Himalayan Blackberry in Western Oregon is of particular concern due to the massive barriers the plant creates and its stubbornness of eradication. A spatially stochastic model is used to predict the spread of the blackberry in Oregon, taking into account factors such as elevation, annual rainfall, temperature, urban sprawl and black bear ranges.

1 Introduction

Himalayan blackberry is one of Oregon's most notorious weeds. Ranked B by the Oregon Department of Agriculture, it has taken over an extensive portion of the state. As for methods for control, total eradication is not possible. Currently, it is considered that spot treatment on a case by case basis is most economic method of controlling the species. In this paper we will model the spread of Himalayan Blackberry in Oregon mathematically using stochastic methods.

2 Background

Himalayan Blackberry (*Rubus Armeniacus*, *Rubus Discolor*, and *Rubus Procerus*) was first introduced in Marion County in the late 19th century for cultivation. It was found released in Marion County in 1922 [14]. By 1945 it was listed as a noxious weed. In 2005 Himalayan Blackberry had spread along the length of the Oregon coast [8, page 116, 118]. Gray also states that mapping plots of the invasive species is the most effective method to assess the invasion of nonnative species [8, page 110]. Consequently, the objective of their paper was to assess the climate and site quality of the plots of Himalayan Blackberry in Western Oregon. An unfortunate part of Gray's study that they admit is that the study does not account for Federal land, since certain data was not available in the studies of land owned by the Bureau of Land Management. One of the most important variables when studying invasive plant species in Oregon is elevation. In Western Oregon, elevation is generally correlated with temperature, but not precipitation [8, page 123]. Also, with blackberry, basal area had a more negative association with frequency than did canopy cover. This might mean that blackberry is more persistent in older stands [8, page 123].

Figure 1 shows a map of Oregon with marked areas where Himalayan Blackberry is currently found. Data was taken from the Oregon Department of Agriculture. Note that the berry is found only in the coastal areas West of the Cascades with a dense covering in the Willamette Valley and a sparse covering further south. While Himalayan Blackberry is rarely found East of the Cascades, it has invaded in the north eastern corner of Oregon.

Himalayan Blackberry reproduces via cloning and seed production. *R. Armeniacus* can produce 720 fruits per cane, compared to the native *Rubus Ursinus*'s 23 per cane [13, page 106]. The fruits are picked up by other animals, eaten, and spread in this way. The Himalayan Blackberry can produce up to 13,000 seeds per square meter [9]. The Himalayan Blackberry also root-tips, meaning the canes can touch the ground and grow a root system so that the plant can slowly radiate from the original stalks. They also produce daughter plants, where the root system extends horizontally and canes grow up from the ends of the root system. Since Himalayan Blackberry is commonly found in riparian habitats, the fruits of the berry can travel downstream [9].

Himalayan blackberry shows up in very open patches. In 2006 Caplan found that Himalayan Blackberry had a higher level of photosynthesis irradiance than its fellow natives [3, page 14]. Though the berry typically prefers new, disturbed riparian habitats, it has also been found in Early

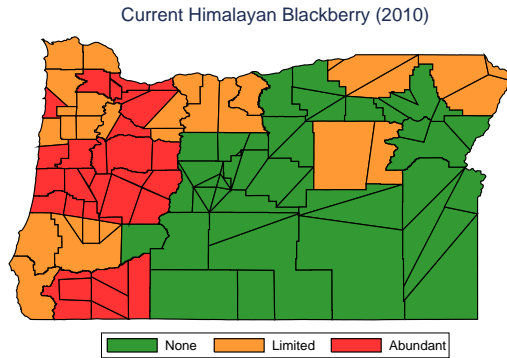


Figure 1: Known Himalayan Blackberry plots 2010

and Late Seral forest stages [6, page 378]. With soil, most of the samples where the Himalayan Blackberry was found had high sand, low silt, and low clay content [3, page 14]. Himalayan blackberry is also known to tolerate drier soils than are typical in Oregon [3, page 14]. Himalayan blackberry likes temperatures around 4.4 to 26.7°C as well as an average annual precipitation of 110 cm [6, page 377]. The berry exists in wide ranges of precipitation, occasionally in locations with as few as 50 to 305 cm per year and elevations of less than 1370 meters (taken from geographical maps of Oregon provided by the Oregon Climate Service).

Some current control methods include cutting stalks and using spot-treatment pesticide glyphosate or triclopyr when the stalks grow back to 18 inches [12]. Some have considered blackberry rust, *Phragmidium violaceum*, which was introduced in 2005 in North America by accident. However, it also infects Evergreen Blackberry, and although the Evergreen is also a nonnative species to the Pacific Northwest, it is not an aggressive species and is used for cultivation of Blackberry crops which is a multi-million dollar industry in Oregon [10, page 581]. Another popular method for blackberry control is goats. The goats are known to eat the new foliage of the plant but not the older canes, thus they are not an effective control strategy, since Himalayan Blackberry will grow back after the goats leave [12].

Himalayan Blackberry has a higher probability of seed germination when the seeds undergo endozoochory [1], which means animals eat the fruits and defecate them farther away. When animals use the fruits as storage, it's called dyszoochory. When animals are not eating the fruits, small animals generally travel 30 meters to place seeds, squirrels a little farther [18, page 116]. Small birds carry them about 60 meters, and large birds such as Jays and Crows travel within a few hundred meters [18, page 116]. Endozoochory data for small animals does not exist [18, page 117], but larger animals are considered for their wider migration areas. The largest animals that eat blackberries in the Pacific Northwest are deer, (white, black tailed and mule deer) as well as black bears. Since black bears have a large home range and travel widely, they are considered a force of interest in seed dispersal of Himalayan blackberry.

It is estimated that there are about 25,000 to 30,000 black bears in Oregon [16]. Black bears are found in the Coast Range, Siskiyou, Cascade, Willowa and Blue Mountains [15, page 101]. Figure 2 shows a map of the range of Black bears in Oregon. Black bears have a home range of about 2-6 sq miles (3219 to 9656 m) for females and up to 100 sq miles (160934 m) for males. While data for the seed dispersal distance for American black bears is not available, it is known that Asiatic Black Bears can transport seeds up to 22000 meters [11, page 287].

Previous attempts at modeling the spread of invasion of *Rubus Armeniacus* are few. The Alaskan Fish and Wildlife service has maps of prime areas for the spread of Himi over then next 50 years [2]. They used a program called Akepic which stands for Alaska Exotic Plants Information Clearinghouse, and it is essentially a huge database of Alakan plants and their current locations [2, page 9]. In Dehann’s article of 2007, maps have been created to capture the spread of Himalayan blackberry in Austrailia using special computer software [5].

3 Methods

3.1 Data Collection

To model the invasibility of Himilayan Blackberry the following factors will be considered are temperature, elevation, annual percipitation, rivers, urban growth boundrys, range of black bears and areas of known blackberry coverage. Also, a map of the old growth forests would be useful, but since these forests are scattered around Oregon, it was easier to account for the amount of disturbed land with the urban area map. A map of each influentail factor was made by cutting the county lines of Oregon into areas that were suitable or not for Himalayan Blackberry.

Oregon’s average temperatures are known for being in the temperate zone with the western coastal region being moist and warmer. East of the Casacde mountain range has less precipitation and more extreme temperatures with an average of 20°C in the winter. However, Himilayan Blackberry is found in regions of Alaska that are well below freezing temperatures in the winter, thus the berry is frost resistant. By examining the current distribution of Himilayan Blackberry , one can assume that the berry prefers slightly warmer, temperate moist enviroments such as costal regions. We took a county map of Oregon and made cuts across county lines that divided the regions into areas that would be suitable for blackberry according to temperature. Each factor map was gridded in a similar way.

After examining the range of black bears and comparing them with the average size of the cut regions, it was determined that black bears could not transport seeds more across more than one region. This is because most of the regions that were cut were at least 20 miles wide in any direction. If we look at the maximum range of black bears, the home range of the male bears, it is 100 sq miles. Thus, the presence of black bears in certain regions increased the invasion in those regions as well as thier neighbors.

3.2 Homogeneous Regions

A composite map of the cuts was made of Oregon from all the individual factor maps. Thus, every cut region of the map was homogeneous with repect to all the indicators of habitat and spread. The total amount of homogeneous regions was 105, with blackberry currently inhabiting 60 of those regions, 41 of those regions moderately invaded and the other 19 regions being highly invaded. Using computer programming in C, the probabilities of dispersal of Himilayan Blackberry were estimated.

3.3 Implimentation

Consider the following ODE, which would be the ideal modeling of the spread of Himilayan Blackberry :

$$\frac{dH_i}{dt} = Bs_iH_i + \sum_{j\text{neighbor}} Db_{ij}(H_i - H_j)s_i, \tag{1}$$

where H_i is the level of infestation in region i and $s_i = a_it_r_i e_i u_i v_i$ However, ODE models are too precise for our data When we impliment the Stochastic model, we are taking the

rates of the ODE model and interpreting them as probabilities of events. For example, when considering factor map with only two variables, the regions that were considered more desirable by Himilayan Blackberry , the probability of survival in that region was represented by one. Likewise, the unsuitable region was represented by a number between 0 and 1, usually less that 0.5.

Regions that were more suitable with respect to Himilayan Blackberry factors were given a higher probability of invasion within one timestep. Himilayan Blackberry was assumend to spread only between contiguous regions, with a higher probability if the length between the boundry of the two regions was longer. The Gillespie algorithm was used along with these event probabilities to generated simulated invasion possibilities [7]. To determine suitable parameters, data from the initial invasion of *R. Armeniacus* in 1922 in Marion county was used as initial conditions. Parameters were selected so that after 88 years the invasion of Himilayan Blackberry matched the current blackberry distribution in Oregon. To determine the spread of Himilayan Blackberry in the future, we then ran the model for 20 more time steps (or years) to project our estimates into the future. The Gillespie algorithm was implemented in C [4] and Stata [17] was used to produce maps of the results.

4 Results

4.1 Input

Figures 2-5 show the individual factor maps of current conditions.

4.2 Marion County

Data of Marion county being moderately infested with Himilayan Blackberry from 1922 was used as initial conditions for the model. We also had to consider that at some point the Northeastern county of Oregon, Wallowa, had to be moderatley infested in 1922 in order for our model to predict current spread accurately. This is a probable assumption because of the agriculture prominence of the Blue Mountain region. The model was run for 88 years and parameters were adjusted so that the resulting spread accuratley modeled the distribution of Himilayan Blackberry in 2010.

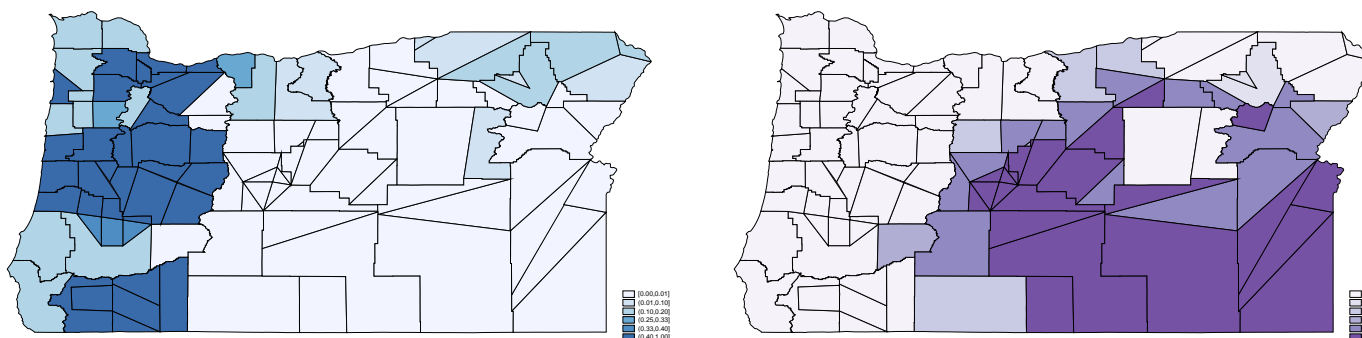


Figure 2: 2030 predicions indicating probability of high intestation (left) and no infestation (right)

4.3 Future

After the parameters were adjusted, we used the same parameters on data from current spread of Himalayan Blackberry in 2010. The model was run 20 years in the future, and below are the graphs we got from this analyzed. In Figure 5, we can see that the darker shaded regions of the map are areas that have a high probability of being highly infested in 2030. Similarly, in Figure 6 we see that areas that are shaded darker have a high probability of never being infected by Himalayan Blackberry .

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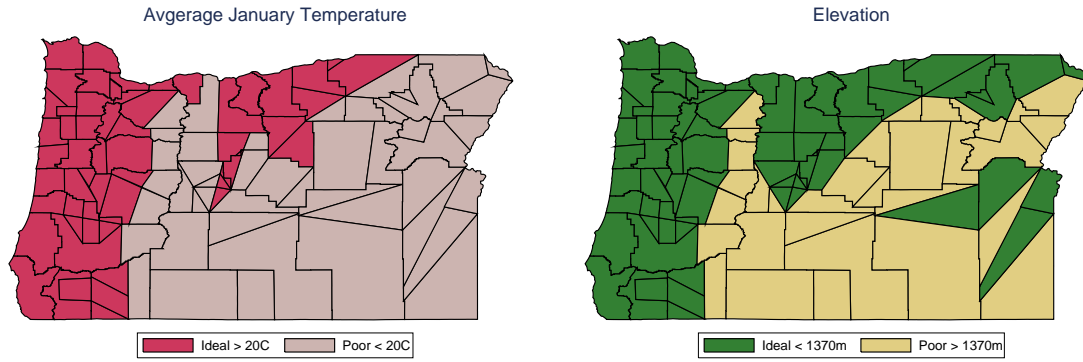


Figure 3: Temperature and Elevation factor maps.

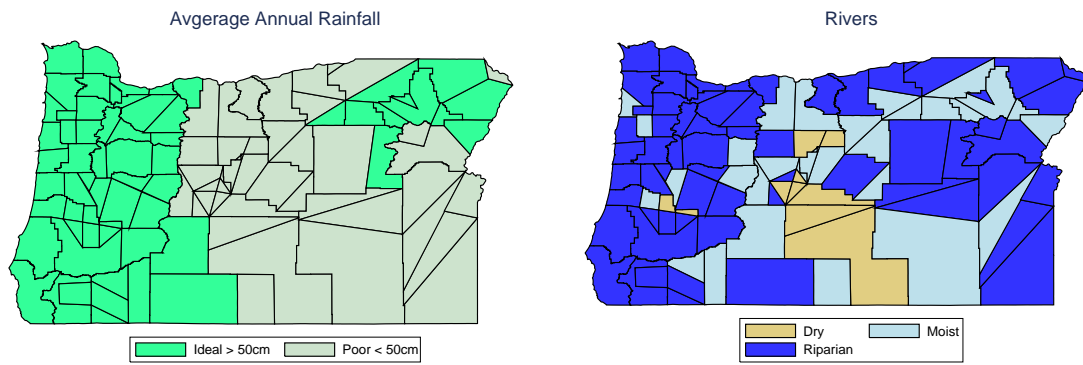


Figure 4: Rain and River factor maps.

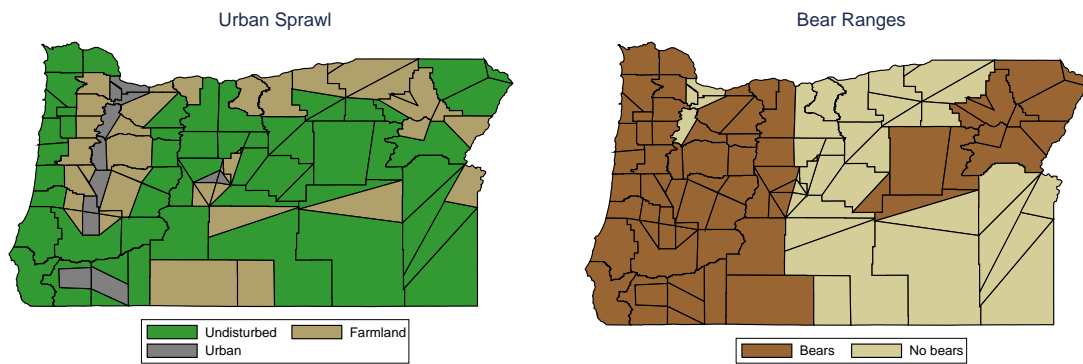


Figure 5: Urban and Bearfactor maps.

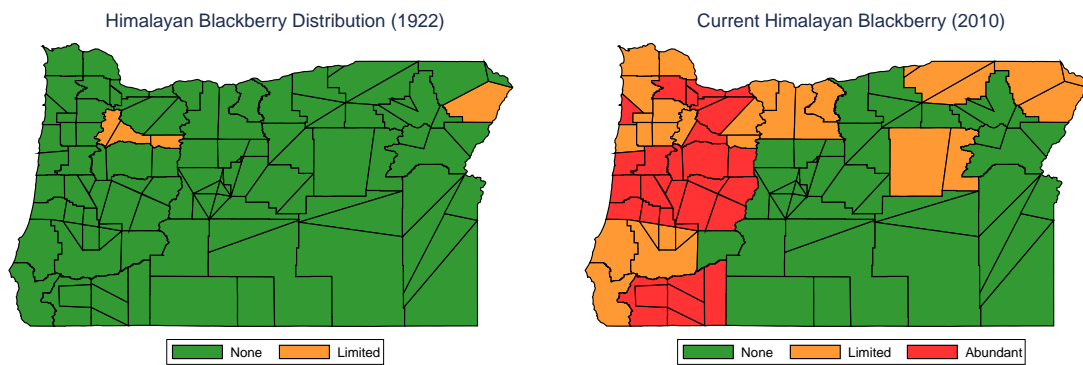


Figure 6: Distribution of Himilayan Blackberry in 1922 and 2010