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Geospatial analysis on the influence of biophysical factors on the gall rust prevalence in falcata (*Paraserianthes falcataria* L. Nielsen) plantation in Gingoog city, Philippines

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Abstract

This study was conducted to provide additional information on the prevalence of gall rust disease in falcata plantations. A geospatial analysis was employed to determine the influence of biophysical factors to the prevalence of gall rust. The study was conducted in a falcate (*Paraserianthes falcataria)* plantation in 5villageswithinGingoog City, Philippines. Stratified sampling were followed based on elevation range. Geospatial analysis and mapping was executed using Arc Map ver. 10.1. Result showed that percentage of healthy falcata decreases as the elevation increases and begun to decrease significantly at 400m asl. Severe cases were found at elevation ranging from 400 to 600m asl. Multiple linear regression analysis showed that 22.7% of the variation in infestation rate can be explained by diameter and elevation. Mature trees seemed to have higher tolerance to the disease as no death in mature stand was observed and has not succumbed to the disease. The galls caused death or serious injury to seedlings and saplings, which will potentially lower wood quality and thus will reduce the price of the timber. It was recommended that commercial plantation of *P. falcataria* will be limited to elevation 300m asl and below. Regular monitoring, removal and burning of infected plant parts until the plantation passed sapling stage was also recommended. The kriging interpolation method has proven to be an effective tool to be able to generate a health map which can serve as guidance for the farmers in selecting areas suitable for *P. falcataria* with respect to gall rust disease.

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Introduction

Paraserianthes falcataria (L.) Nielsen, Fabaceae (Mimosoidea), locally known as falcata is one of the most important fast growing tree species in some regions in Mindanao, Philippines. This species is now the main raw material for pulp and paper, making it a major dollar earner as log export in the Philippines (Anino, 2000) and can be used to produce high value-added wood products (Nemoto, 2002). Plywood manufacturing companies preferred this tree species because of its ability to grow in variety of soils, fast growing and acceptable quality of wood for panel and plywood industries (Krisnawati *et al.*, 2011). The wood is lightweight, soft to moderately soft with density ranging from 230 to 500 kg/m3 at 12-15 % moisture content (Varis, 2011) which favors efficient transport and loading. *P. falcataria* is also preferred by farmers as intercropped (Nissen *et al.*, 2001) in the study site, *P. falcataria* were intercropped with coconuts, bananas and fruit bearing trees. Truckloads of *P. falcataria* logs supplying mini sawmills are mainly grown by smallholder farmers with an estimated annual production of 45,000 to 53,617 m^3 in one region alone since 1996 (Bertomeu, 2003).

A very damaging gall rust disease had affected *P. falcataria* for decades in the Philippines. It is caused by *Uromycladium tepperianum* (Sacc.) Mc Alpine but a recent study by Doungsa-ard *et al*, (2015) revealed that the rust on *P. falcataria* differed from *U. tepperianum* thus *Uromycladium falcatarium* sp. nov. was described to accommodate this taxon, which can be differentiated from other species of *Uromycladium* by teliospore wall morphology, host genus and DNA sequence data. The disease caused the formation of galls on foliage and branches that resulted to massive defoliation of the tree crowns and eventually death (Old and Cristovao 2003), it can affect all growth stages from seedlings to mature trees (Rahayu *et al*, 2010)In the Philippines, the disease was first observed in early December 1988 in an experimental falcata plantation at the vicinity of the laboratory of the plant protection research section of Forest Research Division, Paper Industries Corporation of the Philippines (PICOP) (Anino, 1991) and has devastated *P. falcataria* plantations in the country since. The disease were also observed in neighboring Asian countries (Old and Cristovao 2003, Lee 2005, Rahayu2007, Rahayu, 2008). Currently only cutting and burning of infected plant parts were recommended and cessation of planting in areas with elevation higher than 250 m asl. (Anino, 1994). This study aimed to investigate the influence of elevation to gall rust occurrence considering other biophysical factors and generate a map that would guide tree growers on suitable site for falcata plantation.

Material and methods

The study was conducted in small scale falcata plantation in Gingoog city, Misamis Oriental, Philippines. Five barangays (villages) within the city was selected based on accessibility. Patches of falcata plantations within these villages constituted the whole population. The site was divided into 6 subgroups (strata) based on elevation range corresponding to 0-100, 101-200, 201-300,301-400,401-500 and 501-600 masl as strata.

Inventory

A 100% inventory was conducted since the plantation is less than 1 ha in every strata. Tree height were measured using clinometer for higher trees and improvised meter stick for shorter trees. Tree height were classified into small, medium and large corresponding to 1-7 meters, 8-12 and greater than 12 meters respectively. The diameter of trees was measured at breast height using a tree caliper and was classified into seedling, sapling, pole and standard tree with the corresponding diameter in cm to less than 5, 2-15, 18-25 and greater than 25 respectively.

Individual trees were inspected for presence of galls and the intensity of infection was classified according to the number of gall present per tree as: lack, weak, average and high corresponding to 0- l0 %, ll-25 % and 26-60% and 6l-99% of the crown infected respectively following (Lakomy and Iwariczuk, 2010). Soil sampling and interpolation.

For soil analysis a composite sampling method was followed (Patil, 1995). Soil sample was obtained from sample plots per elevation class. Samples of top soil (1 meter from the surface) and subsoil was collected in every stratum. At least 3 samples both top and sub soil representative of every patches for every stratum were collected. The collected samples were then mixed thoroughly and only 1 kilo of it was used for analysis to determine type of soil, Soil ph, NPK, water holding capacity and organic matter content.

Geo-spatial and Data Analysis

To ease the researcher in illustrating the extent of gall rust occurrence, spatial analysis using Arc Map ver. 10.1 was utilized. A digitized map of the site was obtained. The GPS coordinate readings from the sample points containing the information on gall rust prevalence such as percentage and intensity of infection was used to generate raster GIS data model. The method employed Krigging interpolation technique of the spatial analyst tool within the Arc Gis 9.3 software of ESRI. Soil data were also interpolated using this technique.

The generated raster data file was used as input in a form of digital elevation model (DEM) to derive thematic maps on the extent of gall rust in the study site.

The stepwise multiple linear regression analysis was executed using SPSS software to determine which factor or combination of bio-physical factors can best predict the occurrence of gall rust disease.

Results and discussion

Disease Prevalence

Figure 1 shows the result of the actual survey conducted. Gall rust infection occurred in all elevation class. Severe cases were found at elevation ranging from 400 to 600m asl in which average to high intensity of infection was observed.

Table 1. Mean intensity of infection (percentage of the whole crown with galls) per tree per elevation class (Mean ± SEM).

Elevation range	Mean intensity of infection/tree %*
0-100	1±.56 a
101-200	1.2±.40a
201-300	9.85±.59a
301-400	9.56±2.35a
401-500	24.22±2.86b
501-600	26±1.55b
600-700	25.04±2.10b

*means followed by same letter are not significantly differently (Tukeys HSD: P<.05).

The elevation that had the highest percentage of infection was at 500m asl and above in which 92% of the total number of trees in this elevation were infected with the disease. Very small occurrence was found at 0 to 100m asl elevation range. Only 3 out of 30 individuals were infected.

But the intensity was classified as lack (10% of the crown were infected). As shown in Table 1, the intensity of gall rust disease was significantly higher (P<.05) at elevation 400 and above.

Similar results were observed by Anino (1991), that slight infections generally occur at lower elevations ranging from one to 250 meters asl and heavy infections occur at elevations ranging from 275 to 500 meters asl.

Galls were usually seen in shoots and in young succulent stems. The disease occurred in all growth stages from seedling to standard tree consistent with the observation of (Rahayu *et al.*, 2010).

Table 2. Regression Analysis, Dependent Variable: Rate of infection. R square = .227.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	6.430	3.163		2.032	.043
Elevation	.050	.005	.352	9.599	.000
diameter	-.807	.127	-.233	-6.362	.000

However average to high intensity of infestation was only observed in seedling to sapling stage which resulted to deformation of trees and heavy defoliation and few death although total mortality caused by the disease was not obtained since farmers regularly monitored their plantation and dead individuals were replaced. Nonetheless no death on mature trees were observed.

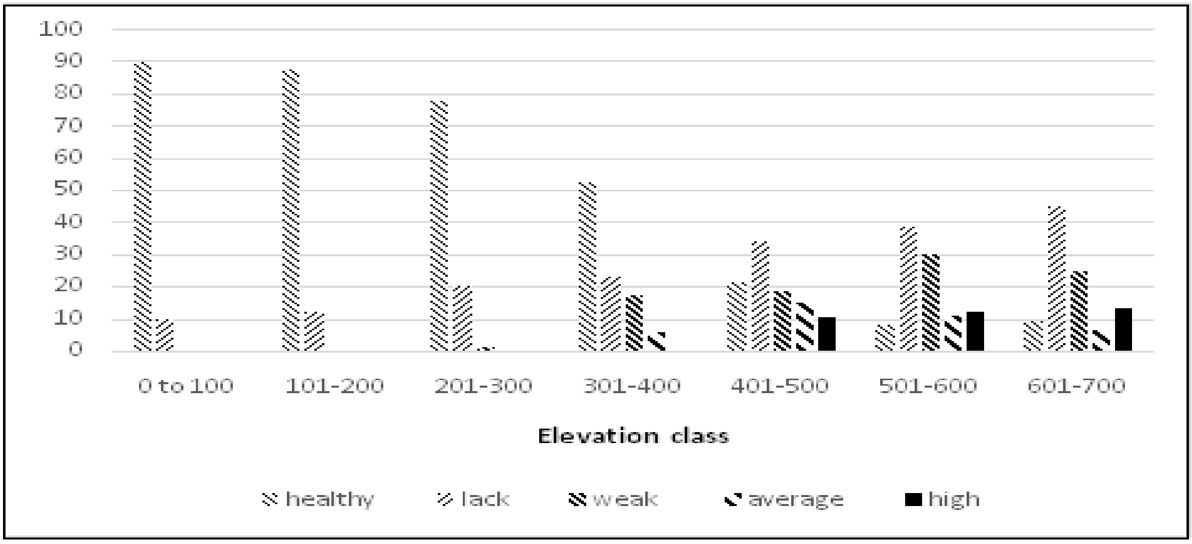

Fig. 1. Intensity of disease per elevation class based on the actual survey conducted.

Geospatial and Data Analysis

Table 2 shows the result of the stepwise multiple linear analyses. The final regression equation derived was:

$Y= 6.40 + .05x_1 - .81X_2,$

Where:

Y= Infection rate

X_1= Elevation

X_2 = Diameter

This regression model (excluding aspect, soil data, and height of trees) was significant ($P<.05$).The equation only explains 22.7% of the variations in infection rate. As the elevation increases, the rate of disease occurrence also increases. Successful infection and spread of gall rust disease is dependent upon the favorable conditions for growth and development of the causal agent (*U. falcatarium*).

In this case high elevation areas, usually has high relative humidity and heavy fog which favors gall rust development (Rahayu, 2007). High relative humidity (RH ≥ 90%) and slower wind speed (WS ≤ 80 km/hours/day) were able to promote gall rust disease development (Rahayu *et al.,* 2010, Rahayu, 2012). On the other hand, as the diameter of falcata increases or as the tree matures the intensity of gall rust decreases. Although gall rust disease infects all developmental stages of the *P. falcataria* from the nursery stage to mature trees. In the field, only seedling to sapling stages were found to be seriously affected and no mortality in mature trees was observed. Mature trees seemed to tolerate gall rust disease. According to (Young and Giese, 2003) some pests exploit smaller, suppressed understory trees and very old or slowly growing trees can be particularly damaged. Anino, (1991) explained that

Infected saplings, cease to grow because their topmost growing parts are either transformed into octopus-like structures or bent downward which causes adverse disruption of water and nutrient uptake and photosyn that translocation, resulting in stunting and eventual death of the plants.

Currently there was no control measure known for gall rust (Su-See, 1999). Cut and burning on infected plant parts was recommended to prevent dispersal and further infection to neighboring trees and plantations (Anino, 2000). Application of chemical control was discouraged due to its negative impact on the environment (Old and Cristovao, 2003).

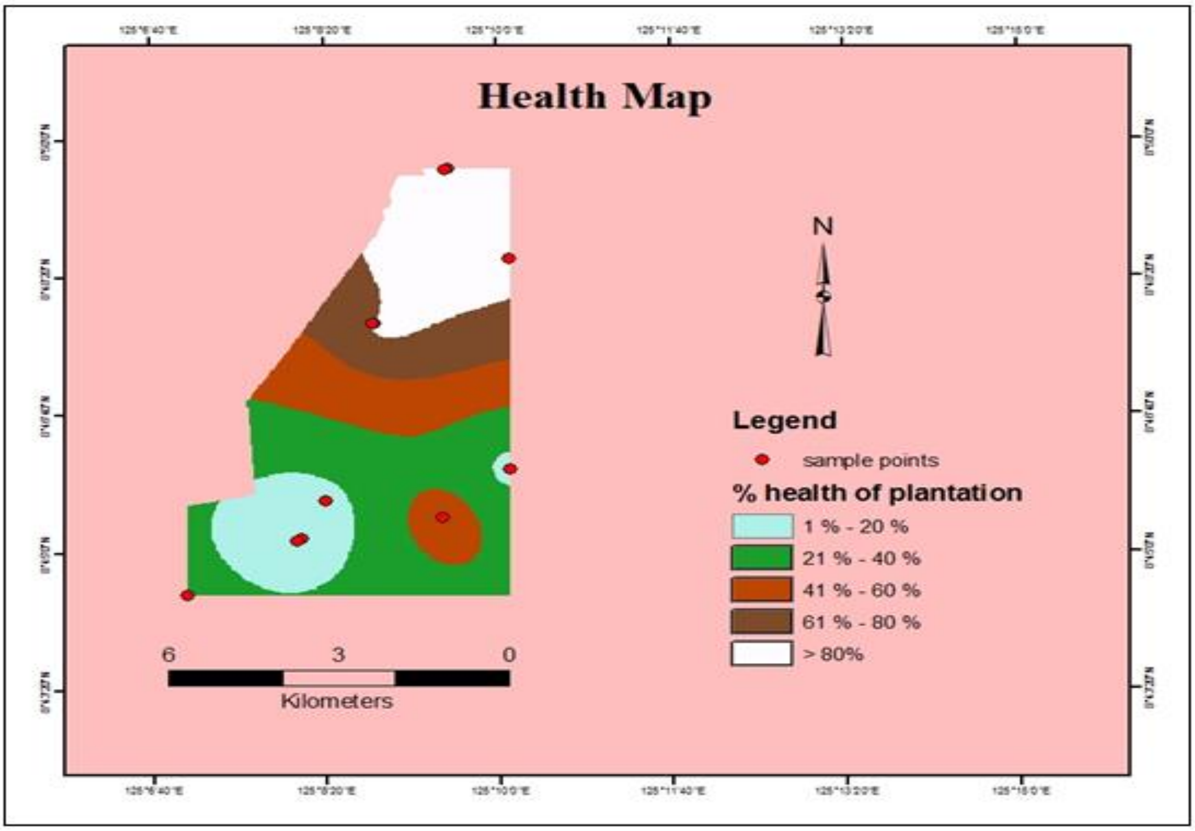

Fig. 2. Map generated using krigging interpolation technique of the spatial analyst tool of arcmapver 10.1. Covering 5 villages within Gingoog City, Philippines.

Kriging interpolation using observation points (x,y,z) of the health status of falcata has proven to be an effective way of generating a health map. The health map also illustrates a continuous (raster) suitability map for *P. falcataria* across Gingoog City. This map would greatly help plantation managers in delineating areas suitable for *P. falcataria* plantations considering bio-physical factors. Kriging is synonymous with optimal prediction or with optimally predicting, it refers to making inferences on unobserved values by computing weighted averages of sampled values from nearby locations (Cressie 2005, Morin *et al*, 2015).

In Fig. 2, the health map as an output of the interpolation is displayed. Locations with predicted prevalent gall rust disease and healthy plantations can easily be delineated. A related study has employed kriging, it was used to assess spread of disease (Martins, 2007) simulation of the effects of climate change to activity of forest-pathogenic fungi (Desprez-Loustau, 2007)

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