Tree corridor planning for the ecological sustainability of agricultural area in Sekaran Village, Bojonegoro Regency

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Abstract. Drought is the main problem faced in agricultural activities in Sekaran Village, Bojonegoro Regency. The primary agricultural commodities in Sekaran Village are corn and cattle breeding. Tree corridor planning is one of the proposed solutions to overcome this problem. This study aimed to develop a tree corridor plan for the agricultural area's ecological sustainability in Sekaran Village by improving the quality and quantity of green open space. Spatial data obtained from the field survey using drone technology. Environmental variables used for corridor plan analysis were land cover, slope, road, and orthomosaic imageries. This study produced a tree corridor planning along 156.57 km located in agriculture land, roadsides, and valley/basin. The proposed tree species has ecological functions such as water absorption and improving microclimate, production functions (food and cattle feed), and aesthetic functions. Tree corridors will use a hedgerow model to form an integrated corridor system in Sekaran Village. Tree species recommended such as Swietenia mahogani, Delonix regia, Spathodea campanulata, Gliricidia sepium, Centrosema pubescens, Leucaena leucocephala, Mangifera indica, Artocarpus heterophyllus, Psidium guajava.

1. Introduction
Sekaran Village is one of the villages that can develop for agribusiness activities in Bojonegoro Regency. Agricultural commodities in Sekaran Village include corn and cattle breeding. Bojonegoro Regency is a lowland area near the Bengawan Solo river with commodities from crops to plantations, like rice, corn, coconut, tobacco, and teak [1]. However, drought is one of the main problems for the sustainability of agricultural activities in Sekaran Village. Drought is a severe problem of water supply, especially in dry weather [2]. This condition occurs when reservoir levels are lower than average, leading to unrepaired damages to both nature and socio-economy [3][4]. Therefore, most plants planted in this village are mostly corn and teak because these two plants are more resistant to drought conditions. Besides the drought, the landscape of Sekaran Village looks arid due to the lack of trees, especially in the dry season. The existing trees are dominated by teak trees (Tectona grandis), which in the dry season will shed their leaves so that visually the Sekaran Village landscape currently looks barren during the dry season.

Landscape structures include corridors that are narrow physical or functional belts, and in other cases, corridors can be identified structurally, such as hedges [5]. A hedgerow is a line of closely spaced shrubs and tree species, planted and trained to form a barrier or to mark the boundary of an area and also to separate a road from adjoining fields or one field from another [5]. The corridor affects the absorption
and erosion rate of water when the rainy season comes [6][7]. In agriculture, tree cover interspersed, which influences landscape connectivity [6], and it's vital to control the spatial and annual cycle of the hydrology process [8][9][10]. The function of an integrated tree corridor is as an area to increase water absorption, improve environmental quality, and visual aesthetics. Hedgerows, especially in agroforestry is a practice in a rural landscape that contribute to landscape connectivity and biodiversity conservation [6][7][11][12][13][14][15]. Therefore, the one solution is proposed to overcome the problems in Sekaran Village is the tree corridor.

This study aimed to develop a tree corridor plan for the agricultural area's ecological sustainability in Sekaran Village by improving the quality and quantity of green open space. Besides its functions in the agricultural area, this corridor also plays a role in conservation planning to promote biological connectivity [11][16].

2. Methods
This study was conducted in Sekaran Village, Bojonegoro Regency, covering about 1.676,56 ha (Figure 1). This village consists of three hamlets there are Jarwetan, Jarkulon, and Ngantru. There was a teak plantation area managed by Perhutani (Indonesian state forestry company) between Ngantru and Jarkulon-Jarwetan. Cattle breeding was dominated in Ngantru, and corn fields were dominated in all hamlets.

![Figure 1](source: orthomosaic imageries)

2.1. Field survey
Drone flights were carried out during the field survey to obtain spatial data in Sekaran Village. Satellite and manned aircraft have been used to monitor the dynamic vegetation and drought conditions [2][3][10][17], because of provide high spatial resolution and low-cost way of monitoring vegetation in
landscape-scale [10][18][19]. The drone flight was carried out for seven days using two drones at the Ground Control Point (GCP), which marked at the outermost boundary point of the village and several midpoints in each village during the field survey. GCP is a permanent marked using concrete in a grid's intersections according to the horizontal and vertical coordinates [10].

2.2. Spatial analysis based on drone data
Spatial database results based on drone mapping are in the form of orthomosaic maps, Digital Elevation Model (DEM), land cover, and 3D visualization. Orthomosaic image sizes amount to dozens of gigabytes cause it's originating from hundreds to thousands of UAV photos [10][19]. The data from DEM can then be used as primary data for making maps of elevation and slope. In addition to orthomosaic and DEM data, the contours and land cover of Sekaran Village were also obtained from the results of drone-based ground surface analysis.

2.3. Tree corridor planning
Tree corridor planning is analyzed by overlayed of elevation, slope, land cover, and orthomosaic imageries. After the analysis, the tree corridor planning decided the corridor type, width, length, area, and tree species. The tree species recommends for corridor which has ecological functions such as water absorption and improving microlclimate, production functions (food and animal feed), and aesthetic functions. The tree species recommended in this study were obtained from research recommendations and community preferences obtained through interviews with 12 key informants in the Sekaran Village. We also make a planned tree corridor in 3D illustration compares to the existing condition of Sekaran Village.

3. Results and discussions

3.1. Spatial data
Spatial data is obtained from the results of analysis based on drone data. The spatial data includes the orthomosaic map, road map, elevation map, slope map, and land cover map (Figure 2). On the orthomosaic map (Figure 1), it can be seen that the existing condition of Sekaran Village in September was in drought season, especially in the Perhutani area because of planted with teak. Based on the elevation, slope, and contour maps, it is known that Ngantru hamlet is the area with the highest point in the northern part of Sekaran Village. Jarwetan and Jarkulon hamlets are the lowest points in the southern part of Sekaran Village. Sekaran Village dominated by 45.92% (768.78 ha) slope in 3 – 8 %, 38.84% (667.95 ha) elevation in 50 – 75 masl, and 63.36% (1062.19 ha) landcover of corn. This condition proves that Sekaran Village is located in the lowland with agricultural activities as the dominant land use/cover. The distribution area of slope, elevation, and landcover in Sekaran Village can be seen in Figure 3.

3.2. Tree corridor planning
The tree corridor planning intends to improve the quality of green open space in Sekaran Village. Tree corridors will use a hedgerow model to form an integrated corridor system. The tree corridor planning in Sekaran Village is divided into three types of corridors with various width depending on the locations: roadsides corridors, agricultural land corridors, and valley or basin corridors (Figure 4). Corridor width and vegetation composition is an excellent proportion that has a significant role as a catchment area [15][16][20]. This corridor is vital in ecological conduits that have been used in conservation planning and biological connectivity, especially in the valley margin [11][16][21]. This corridor also has some functions as reducing wind velocity, limiting odors from the livestock industry, increase carbon sequestration, and reduce sediment in rivers or streams [6][7][12][13][14]. Detailed information about the corridor and vegetation types in Sekaran Village can be seen in Table 1.
Figure 2. (a) Slope map, (b) Elevation map, and (c) Landcover map
Figure 3. The distribution area of (a) slope, (b) elevation, and (c) landcover in Sekaran Village

Table 1. Tree corridor planning

| Corridor type           | Width (m) | Length (km) | Area (ha) | Tree Recommendation                                                                 |
|------------------------|-----------|-------------|-----------|-------------------------------------------------------------------------------------|
| Roadsides corridor    | 5         | 14.25       | 8.01      | Mahogany (*Swietenia mahogani*) African tulip tree (*Spatodea campanulata*) Flamboyant (*Delonix regia*) Bougainvillea (*Bougainvillea*) |
| Agricultural land      | 0.5-1     | 133.72      | 20.21     | Gamal (*Gliricidia sepium*) Butterfly pea (*Centrosema pubescens*) Lamtoro (*Leucaena leucocephala*) Mango (*Mangifera indica*) Guava (*Psidium guajava*) Jackfruit (*Artocarpus heterophyllus*) Papaya (*Carica papaya*) Soursop (*Annona muricata*) |
| Valley or basin        | 100       | 8.59        | 76.94     | Intercropping between Teak (*Tectona grandis*) and Corn (*Zea mays*) Intercropping between Mango (*Mangifera indica*) and Feed Grass |
Figure 4. Tree corridor planning in Sekaran Village

The roadsides corridor is located on the main road of Sekaran Village and the vegetation arrangement design is in a zigzag pattern with a width of 5 m. The tree species that is recommended along the roadside corridor are shade trees such as *Swietenia mahogani*, *Spathodea campanulata*, *Delonix regia*, and *Bougainvillea*. Roadsides tree corridor will improve the visual landscape of Sekaran Village because of using the tree with colorful flowers that bloom and also survive in the dry season.

The agricultural land corridor in Sekaran Village is 50-100 cm wide and uses fast-growing plants that can be used for food sources such as fruit trees and also cattle feed. Vegetation that can be planted for agricultural land used as cattle feed is a legume or Leguminosae. Legumes are known for their benefits as ecosystem services that supply protein-rich food and feed, reducing greenhouse gas
emissions, and diversification of cropping system [22][23]. Examples of legume plants planted under environmental conditions in Sekaran Village are *Gliricidia sepium*, *Centrosema pubescens*, and *Leucaena leucocephala*. Based on community preferences, 76% wanted fruit trees for agricultural land corridors such as *Mangifera indica* (32%), *Psidium guajava* (20%), *Artocarpus heterophyllus* (12%), *Carica papaya* (8%), and *Annona muricata* (4%).

It is proposed that the valley/basin corridor width is 100 m and be planted with an intercropping system such as teak (*Tectona grandis*) with corn (*Zea mays*) or another alternative like mango (*Mangifera indica*) with feed grass. The differences in cropping system is an option to support functional biodiversity [22][24]. This concept involves hedgerows, intercropping, agroforestry, crop rotation, and riparian buffers. Legumes are used in the cropping system, crop rotations, and intercropped with other crops [22][25] corridor. The recommendations tree species mostly used an intercropping system using a production plant with economic values and can be the alternative source of food and cattle feed. 3D illustration design is used to visualize the tree corridor plan in Sekaran Village, Bojenogoro regency. These illustrations show the differences between before and after tree corridor planning is applied. Tree corridor planning and 3D illustration can be seen in Figure 5-7.

**Figure 5.** Tree corridor illustration in roadsides (a) existing roadsides condition, (b) roadsides corridor planning, and (c) 3D illustration of roadsides corridor
Figure 6. Tree corridor illustration in agriculture land (a) existing agriculture land condition, (b) agriculture land corridor planning, and (c) 3D illustration of the corridor in agriculture land

Figure 7. Tree corridor illustration in valley or basin (a) existing valley or basin condition, (b) valley or basin corridor planning, and (c) 3D illustration of the corridor in valley or basin

4. Summary
Tree corridor planning is one of the recommended solutions to overcome the problems faced in Sekaran Village, Bojonegoro Regency. These corridors are divided into three corridor types, roadsides corridor with 5 m width, agricultural land corridor with 1 m width, and valley or basin corridor with 100 m width. Tree vegetation plan has ecological functions such as water absorption and improving microclimate, production functions (food and cattle feed), and aesthetic functions. Tree corridors will use a hedgerow model to form an integrated corridor system in Sekaran Village. Tree species recommended such as
Swietenia mahogani, Delonix regia, Spathodea campanulata, Gliricidia sepium, Centrosema pubescens, Leucaena leucocephala, Mangifera indica, Artocarpus heterophyllus, Psidium guajava.

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