# ABUNDANCE AND DISTRIBUTION OF ODONATA IN DIFFERENT LAND USE TYPES ALONG STREAMS IN JIMMA ZONE SOUTH WEST ETHIOPIA

**MSC THESIS**

**BY**

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# ABBRVEIATIONS AND ACRONYMS

| | |
|---|---|
| EBO | Ecological behavior of Odonata |
| ELDO | Effect of land use type on abundance and diversity of Odonata |
| ILCYM | Insect Life Cycle Modeling (Software) |
| IPM | Integrated Pest Management |
| JUCAVM | Jimma University College of Agriculture and Veterinary Medicine |
| MOD | Morphology of Dragonflies/Damselflies |
| NABU | National Biodiversity Assessment at the Kafa Biosphere Reserve |
| OFI | Odonata families identification |
| SDD | Species diversity of dragonflies |

# ABSTRACT

Aquatic ecosystem especially freshwater ecosystems are sensitive to human activities such as land use change which have significant effect on aquatic organisms. Aquatic insects such as dragonflies and damselflies are sensitive to environmental changes and provide essential ecological services, such as bioindicators of freshwater ecosystem health, and usually used as indicators surface water quality indicators. However, limited studies on the abundance and distribution of dragonflies and damselflies in different land uses types in Ethiopia. This study aimed to assess the distribution and abundance of odonata along streams draining in different land uses in southwest Ethiopia. For this study adult dragonflies and damselflies were counted and sampled along streams draining in three dominant land uses namely forest, mosaic and agriculture in Jimma Zone. From a total of 958 adult odonata specimens collected from thirty sites 425 and 533 were identified as Anisoptera and Zygoptera respectively. The estimated sex ratio was male biased for both Anisoptera and Zygoptera. The abundance of Zygoptera was significantly higher in streams draining in mosaic and agriculture as compared to forest streams while no significant difference observed for Anisoptera. In addition to catchment dominant land use, buffer local condition such as proportion of sunlight and wetland along stream buffer also significantly affected their abundance and distribution. Higher proportion of sunlight in the stream buffer favored the abundance of both Anisoptera and Zygoptera in agriculture and mosaic dominated catchments as compared to forest dominated catchments. Our study showed that catchment land use and local stream buffer condition affect the abundance and distribution of adult odonata. Further study is important to understand the response their larvae and adult odonata to stream water quality and substrate condition.

# 1 .INTRODUCTION

Aquatic insects represent an integral part of freshwater ecosystems and they contribute to various ecological services in the ecosystem (Morse,2019). The use of aquatic insects such as dragonflies and damselflies (Odonata) as indicators of water quality is important in determining the ecological integrity of the freshwater ecosystem as they spend large portion of their lifecycle in water and around water bodies (Adu *et al* .,2022). In addition to local stream buffer conditions, changes in catchment land use type such as proportion of natural forest, agriculture, urbanization and water pollution concentrations have a direct impact on Odonata biodiversity, and landscape patterns and different types of water bodies can also have a significant impact on the Odonata communities structure ( Monteiro et al., 2014).

The abundance and diversity of odonata depict the health status of the aquatic environment (Mahmoud *et al*., 2020). Odonata as aquatic insects have their larva stage living in water and their adult stage as terrestrial insects. This positioned them as a powerful assessment tool for both aquatic and terrestrial environments (Deacon, 2020). Odonata are specifically useful as habitat quality indicators as different species are often restricted to different sites. Therefore, changes in species composition in a community may simply be environmental disturbance, which alters the physical, chemical, and biological characteristics of the water body (Stewart *et al*., 2021). Changes in physico-chemical characteristics such as pH, dissolved oxygen, temperature, and electrical conductivity may affect the community structure of Odonata (Ishak *et al*., 2021). Some physicochemical parameters have been found to affect the diversity of Odonata. Water temperature influences the type and number of species present in a place since they require the optimum temperature to live, thrive, lay eggs, and emerge into adults (Taylor *et al*., 2021). Odonata's predatory ability makes them useful in the biological control of disease vectors such as mosquitoes and freshwater snails and their involvement in the biomonitoring of aquatic ecosystems is attributed to their sensitivity to human disturbance (Adler *et al*., 2019). Regular monitoring of Odonata assemblages may help to determine the effect of human disturbance on water quality (Vilenica *et al*. 2022).

Dragonflies (Anisoptera) and damselflies (Zygoptera) are the two Odonata members that have a diverse range of habitats, but individual species can be distinguished by their preferences for particular habitats, and the majority of species are extremely sensitive to environmental changes, especially those brought on by human activity (Mills et al ., 2017). Odonata are frequently used as indicators of habitat disturbance because of their extreme sensitivity to changes in their environment (Dolný et al., 2021). Odonata assemblage distribution patterns are influenced by a variety of habitat traits (Dolný, et al., 2021). They are extremely sensitive and react to even the slightest changes in their environment (Córdoba et al., 2023).

The adult stages are typically affected by larger-scale habitat characteristics, like variations in land use and riparian vegetation as well as buffer stream buffer condition at local scale. It usually needed resource-rich terrestrial habitats for maturation, feeding, resting, and mating (Palt et al., 2022). On the other hand, larval odonata are directly affected by microhabitat conditions, such as water velocity and biochemical oxygen demand (Silva et al., 2021). Deacon et al. (2020) Reported that the patterns of adult dragonfly assemblages were are also influenced by gradients in vegetation and sunlight.

## *1.1 Statement of the Problems*.

Climate change is happening due to natural factors and human activities. It expressively alters biodiversity, agricultural production, and food security. Changes in habitat integrity, which are associated with the loss of riparian forests, have a substantial impact on changes in the environmental quality of river basins in the tropics (Martins et al., 2021).

Land use type in a river basin can result in changes to the diversity and abundance of aquatic biota due to alteration of the physical features of the habitat and the water quality of rivers and streams in the basin (Fekadu, 2021). The self-purification of water, which is threatened by biodiversity loss ensures the purity of this vital resource (Mishra., 2023).
Nutrient cycling, energy transmission along the food chain, and water self-purification are all critical ecosystem functions that are under threat (Meerhof et al., 2022).

Human activities that degrade or change riparian forests and affect the physical structure of the habitat have a direct influence on the species richness and composition of multiple different groups of organisms (Zermeño et al., 2020). The use of sentinel creatures, or bio indicators of environmental quality, such as insects of the order Odonata, is critical for assessing environmental effects and prioritizing conserved sites in this context (Córdoba et al ., 2023).

Owing to the usefulness of Dragonflies and Damselflies in ecological studies, the assessment of their presence, distribution, and abundance in and around freshwater bodies is of paramount importance (Buczyński et al., 2022).

## ***1.2 General objectives***:

To contribute to the knowledge of the abundance and distribution Odonatas in Ethiopia

## ***1.3 Specific objectives***:

To identify adult dragonflies and damselflies based on their morphological characteristics in southwest Ethiopia.

To evaluate the effect of land use types on the abundance and distribution of adult dragonflies and damselflies in southwest Ethiopia.

# 2. LITERATURE REVIEW

## *2.1 Description of Odonata*

Odonata is an order of insects consists of two suborders, Zygoptera (damselflies) and Anisoptera (dragonflies), respectively (Bybee et al., 2021). The two pairs of narrow, transparent wings, sloping thorax, and long, typically slender body of the adults make them easy to identify; the abdomen is almost always longer than any of the wings (Askew, 2021). They are typically seen flying near water, are large, active during the day, and frequently have striking colors (Sibley and D.A , 2020). Odonatas are ferocious predators as adults, and aquatic larvae are no different.

The number of living species in the order Odonata is small and well known; it is most likely not much more than the 5,000 or so species that have already been described. From the tropics, where they are most numerous and diverse, to the boreal forests of Siberia and North America, odonates are found throughout the world (Cadena et al.,2023). With the exception of Antarctica, they are also present throughout the Southern Hemisphere (Marshall et al ., 2017).

## *2.2 Morphology of Odonata( Dragonflies and d Damselflies).*

The suborder Anisoptera is distinguished by their long bodies and two narrow pairs of intricately veined, membranous wings that, though typically transparent, may have colored markings (Sahayarajet al., 2023).

The front and back wing pairs are shaped differently than those of damselflies. Dragonflies also rest with their wings spread out rather than folded vertically (with the exception of one very small family, Epiophlebiidae) (Kohli, et al., 2021).

The hindwing base is broader then forewing, with different venation and membranule, which is used as a distinguishing feature of the Anisoptera (Suárez et al., 2016).Additionally, dragonflies have enormous bulging eyes that take up most of the head, giving some of them a field of vision that is close to 360 degrees (Land and M.F, 2018).

The eyes touch each other in all Anisoptera except the family Gomphidae . The coloration of the winged adults is varied, with hues ranging from metallic to pastel (Leslie and K.D, 2022). They are large compared to other insects, with some having wingspans of up to 16 cm (roughly 6 inches) (Sharma , 2018).

## *2.3 Behavior and Ecology of Odonata*

### 2,3,1 Behavior of odonata

Adults and larvae, (which have a specialized lower jaw for grasping food) are active or ambush predators (Bowman , 2021). Adults feed insects, which they may catch in flight because of their exceptional flying agility; larvae eat aquatic invertebrates, including frog tadpoles and small fish (Brooks et al., 2020).

Mating is complicated and one of a kind. The male odonata begin by grabbing the female on the back of the head (dragonflies) or the anterior part of the thorax (damselflies) using claspers (caudal appendages) found at the tip of the male abdomen (Kriska , 2023).This is known as the "tandem posture." Male odonata have a spermatozoa-storing organ (secondary genitalia) towards the base of the abdomen.

When the male arcs his abdomen, sperm is transported there from the genital hole at the abdomen tip. The female then bends her abdomen forward, producing the "wheel posture," to touch the male accessory genitalia and receive sperm (Jois et al., 2022). Eggs are placed in water or on plants near water or damp regions, then hatch to create naiads, which are fierce predators of other aquatic animals (in most species). The nymphs develop into the adult flying bug (Mokgoebo, 2019).

### 2.3.2 Ecology of odonata

Dragonflies require warmth (about 20°C) to fly (Castillo et al., 2022). There is a gleaming, insect-like look. Smaller dragonflies and damselflies do not vibrate as much, instead positioning themselves to expose as much surface area as possible to the warm sunlight (Schroeder et al.,2018). During the late season, some dragonflies sunbathe on warm stones when the afternoon air cools, releasing heat absorbed earlier (Crosby , 2020).

Perched dragonflies guard their home ranges from a vantage point such as a stone, stick, or stem. After the noon sun becomes scorching, they may remain in their domains of influence (Hare T, 2022). They may remain in their regions of authority and, rather than seeking refuge in the cool shade of a tree, lift their abdomens to point upwards to stay cool (Lovegrove , 2021). The sun's rays are exposed to as little surface area as feasible. This is referred known as obelizing.

Furthermore, some young adults adopt this strategy to regulate their body temperature (Goldschmidt Jr A, 2018). Sunlight has a significant impact on dragonfly ecology (Susanto et al., 2022). Most dragonflies only fly throughout the day in dry, sunny weather (Knoblauch et al., 2021).The pantala (Pantala flavescens) can, however, fly in the rain as long as the air is warm. Others only appear during hot, overcast weather and at night (Hobson et al., 2021).
There has been a lot of recent study on the physical and vegetation elements that determine the essential aspects of a species' habitat (Faber et al., 2014).

The quantity of sunshine or shade, the amount of still or moving water, the structure of the bankside vegetation, the consistency of the water level, and the degree of weed growth are all important factors (Marsh et al.,2022). Furthermore dragonflies are attracted to glossy water surfaces and may mistake a car's windscreen for a pool due to their propensity for shining surfaces (Gibbons, 2022). Recent research has demonstrated that exotic trees like Blackwattle (Acacia mearnsii) can have a major detrimental influence on native dragonflies by darkening out their generally sunny environments. As a result of removing these exotic trees (Judge,2020).

## *2.5 Flight*

Dragonflies are powerful and agile fliers, capable of migrating across the sea, moving in any direction, and changing direction suddenly (Salami et al., 2019). In flight, the adult dragonfly can propel itself in six directions: upward, downward, forward, backward, to the left, and to the right (Paulson, 2019). They have four different styles of flight (Osváth et al., 2020).

Counter-stroking, with the forewings beating 180° out of phase with the hindwings, is used for hovering and slow flight. This style is efficient and generates a large amount of lift.

Phased-stroking, with the hindwings beating 90° ahead of the forewings, is used for fast flight. This style creates more thrust but less lift than counter-stroking.

Synchronized-stroking, with forewings and hindwings beating together, is used when changing direction rapidly, as it maximizes thrust.

Gliding, with the wings held out, is used in three situations: free gliding, for a few seconds in between bursts of powered flight;

gliding in the updraft at the crest of a hill, effectively hovering by falling at the same speed as the updraft; and in certain dragonflies, such as darters, when "in cop" with a male, the female sometimes simply glides while the male pulls the pair along by beating his wings. The wings are powered directly, unlike most families of insects, with the flight muscles attached to the wing bases.

Dragonflies have a high power/weight ratio and have been documented accelerating at 4 G linearly and 9 G in sharp turns while pursuing prey( Salami et al., 2016).

Dragonflies generate lift in at least four ways at different times, including classical lift like an aircraft wing; supercritical lift with the wing above the critical angle, generating high lift and using very short strokes to avoid stalling; and creating and shedding vortices (Szabo et al., 2018). Some families appear to use special mechanisms, such as, for example, the Libellulidae, which take off rapidly; their wings begin pointed far forward and twist almost vertically (Askew, 2021). Dragonfly wings behave highly dynamically during flight, flexing and twisting during each beat. Among the variables are wing curvature, length and speed of stroke, angle of attack, forward/back position of wing, and phase relative to the other wings (Henderson, 2008).

## *2.6 Flight speed*

Old and unreliable claims are made that dragonflies such as the southern giant darner can fly up to 97 km/h (60 mph) (Paulson, 2019).However, the most reliable flight speed records are for other types of insects. In general, large dragonflies like the hawkers have a maximum speed of 36–54 km/h (22–34 mph) with an average cruising speed of about 16 km/h (9.9 mph). [65]

Dragonflies can travel at 100 body lengths per second in forward flight and three lengths per second backwards (Adlakha et al., 2023).

## *2.7 Feeding*

Adult dragonflies hunt on the wing using their exceptionally acute eyesight and strong, agile flight( Supple, 2020). They are almost exclusively carnivorous, eating a wide variety of insects ranging from small midges and mosquitoes to butterflies, moths, damselflies, and smaller dragonflies( Chandra and Gupta, 2022). A large prey item is subdued by being bitten on the head and is carried by the legs to a perch. Here, the wings are discarded, and the prey usually ingests the head first (Schmidt, 2016). A dragonfly may consume as much as a fifth of its body weight in prey per day. Dragonflies are also some of the insect world's most efficient hunters, catching up to 95% of the prey they pursue.

The nymphs are voracious predators, eating most living things that are smaller than they are. Their staple diet is mostly bloodworms and other insect larvae, but they also feed on tadpoles and small fish (Collins et al., 2029). A few species, especially those that live in temporary waters, are likely to leave the water to feed. Nymphs of Cordulegaster bidentata sometimes hunt small arthropods on the ground at night, while some species in the Anax genus have even been observed leaping out of the water to attack and kill full-grown tree frogs (Incagnone et al., 2015).

## *2.8 Predators*

Although dragonflies are swift and agile fliers, some predators are fast enough to catch them. These include falcons such as the American kestrel and the merlin (Dunne and Karlson, 2017). Nighthawks, swifts, flycatchers, and swallows also take some adults; some species of wasps, too, prey on dragonflies, using them to provision their nests, laying an egg on each captured insect. In the water, various species of ducks and herons eat dragonfly nymphs .They are also preyed on by newts, frogs, fish, and water spiders (Waldbauer, 2021). Amur falcons, which migrate over the Indian Ocean at a period that coincides with the migration of the globe-skimmer dragonfly, Pantala flavescens, may actually be feeding on them while on the wing (Hedlund et al., 2021).

### *2.9 Effect of land use type on abundance and diversity of Odonata sub order*.

Aquatic macro invertebrates are a crucial component of the food chain in tropical aquatic ecosystems (O'Mara et al., 2022). Both larvae and adults are predators of some fingerlings and smaller macro invertebrates in the aquatic food chain (Culler et al., 2014).

Even though several orders of aquatic macro invertebrates live in freshwater habitats, two insect orders .Odonata (dragonflies) and Heteroptera (bugs) contribute significantly to the species richness of aquatic insects in the neo tropics and tropics (Oliveira et al .,2019).

Dragonflies have a lot of potential as a sign of environmental disturbance in terrestrial or aquatic habitats despite having little economic significance (Deacon, C. and Samways,2020 ).Odonata live in sediment, between rocks, or on leaves as a result of their wide distribution, interaction with the environment, and association with macro phytes (Fenoglio et al., 2020). At various spatial and temporal scales, in a variety of physical and chemical environments, macro invertebrates display various distribution patterns (Unique et al., 2017).

Because they rely on the features of their aquatic habitat, odonata larvae are sensitive to changes in their environment (Silva,et al. ,2021). They are therefore frequently used as bio indicators of the purity and well-being of the environment. The structure of aquatic communities of insects, including Odonata, in aquatic environments is significantly influenced by habitat integrity (Rocha et al. ,2023).

Diverse aquatic insects, like Odonata, adapt physiologically and morphologically to cope with the deterioration in habitat quality (Acquah , 2022). According to environmental factors like light, water flow, type of substrate, and the width and depth of water bodies, various species of dragonflies form communities (Buczyńska et al.,2019). Other crucial factors include food, inter- and intra-species competition, susceptibility to drought and flooding, shade, and, most importantly, zoogeography (Apostolopoulos,2022).

Odonata distribution in streams is significantly influenced by the size of substrate particles, the type of organic debris, and the availability of food under various conditions (Cheri,2023). The riparian vegetation also contributes allochthones organic matter, a significant portion of the food base, which has a significant impact on the stream ecosystem (Wang et al., 2018). Alterations in the habitat structure frequently have an impact on the variety and distribution of Odonata larvae(Brito et al., 2021). This increases the likelihood that aquatic ecosystems will use them as indicators of environmental contamination (Peterson, et al., 201).

The effects of pollution loads on the diversity and abundance of communities of Odonata living in variously polluted habitats were examined in this study Maoduš et al .,2022). In particular, the study assessed the traits that can indicate changes, including species richness, species abundance relative to Odonata assemblages, species abundance in relation to individual species abundance, physical integrity of the stream banks, and physicochemical water parameters (Schröder et al .,2020).

Even though the majority of dragonfly species are common in polluted and moderately polluted waters, the findings of this study would clarify the significance of pollution loads and river parameters in regulating the assemblages of Odonata communities in a disturbed river (Perron et al .,2021). Having species that prefer extreme ranges of water parameters as bio indicators would be advantageous for such a river( Manzoor et al .,2021)

# 3. MATERIALS AND METHODS

## *3.1 Description of study site*

The study was conducted in Jimma Zone, Oromia Region, Southwest Ethiopia which is located 352 kilometers southwest of Addis Ababa. Jimma zone is located in the wettest belt of the country with a long-wet season extending from March to October. The zone is a headwater source for large rivers such as the Omo-gibe River and Abay River. In this area natural forest, home garden agroforestry, coffee, and agriculture are among the major dominant land use types.

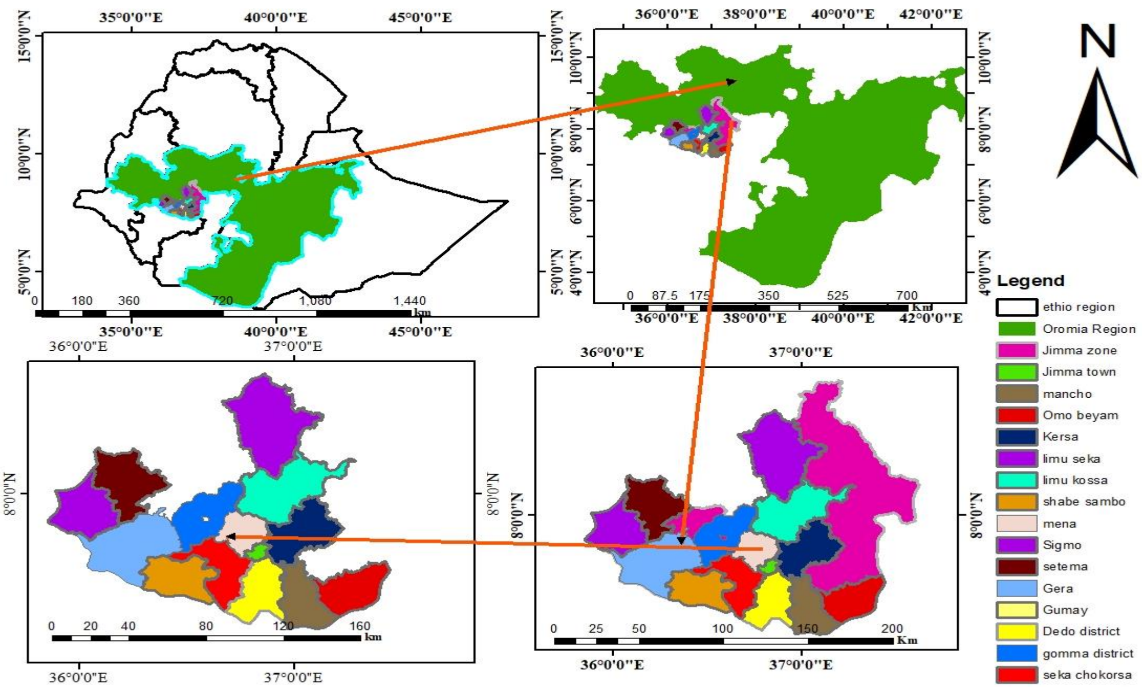



**Figure 1 Sampling sites of river steams in Jimma zone areas**

## *3.2 Selection of study site*

Three dominant catchment land use types such as natural forest, agriculture and mosaic which is composed of coffee, home garden agroforestry were considered to select streams for this study from major tributaries of three major rivers (Didesa, Gojeb and Gibe River) flowing in Jimma Zone. Representative streams were selected purposely considering the three dominant land use types (agriculture, forest and mosaic. For the dominant land use type and stream condition such as , size and availability of water throughout the year were used as a criterion for selection of representative the sample streams for this study (Tian et al .,2019). Accordingly, in total thirty small perennial streams (10 small streams from each of the three land use types) were selected and 100 m long reach was established to sample ,and count adult dragonflies and damselflies (Zhang et al .,2013).

### *3.3 Sampling method and data collection*

### 3.3.1. Count data

Counting and collection of adult dragonflies and damselflies samples were conducted within the selected sample reach for the selected small streams. The collection of Odonata specimens was based on an established scanning sampling technique within a fixed area (Pereira et al .,2021). Adults were sampled along a 100-meter length of each stream. A fixed-point counting method was used to estimate the abundance of adult Odonata along the banks of the selected streams (Doucet et al. 2021). The sample reach (100m) was divided in to four segments and the counting was performed by using good spot to easily count and increase visibility of all flying and perching individuals (Hull et al. 2019).

To make the counting procedure uniform, in each segment the counting was performed for two minutes (Seshadri et al. 2021). All individual flying, sitting on stone and perching on vegetation were counted. During the counting, maximum care was taken to minimize double counting of flying individual (Liu 2021). The counting was performed under optimum weather condition, i.e., presence of sunlight and no or minimum wind speed (Sadati et al. 2021).

Moreover, appropriate sampling time was identified to transect sunny coverage (%), cloud coverage (%), tree shade coverage (%) and rainy time. For this study, a sunny transect route with fairly uniform habitat was considered following route with water's edge as far as possible with transect length 100 m long reach.

### 3.3.2. Insect sample collection

The populations of adult insects of the order Odonata were sampled at three major rivers (Didesa, Gojeb and Gibe River) and their boundaries in Jimma Zone. The adult insects of the order Odonata were samples from the same reach (100 m) using sweep net for further identification and to estimate dragonfly and damselfly abundance (Lee et al. 2021). Sampling was performed during the dry season and sunny day (full sunshine; between 10:00 AM and 4:00 PM) to ensure efficient sampling as these conditions corresponding to the peak of odonata activities (Tesfaye and Habtu 2022).

Additional notes from field observation include the proportion of sunlight and shade cover in stream buffer were recorded during the field work (Padgett et al. 2019). The collected specimens were stored in paper envelope and preserved in deep freezer for farther identification (Kirichenko et al. 2021).


**Figure 2 a single-specimens transect with a length of 100m for length**

## *3.4 Odonata suborder identification*

The collected specimens were identified to suborder level. The identification was performed visually based on morphological characteristics (De Knijf and Van Grunsven, 2015).

The key morphological characteristics include abdominal shape, caudal appendages, compound eyes position. Specimens were identified to sub order level, based mainly on the morphological criteria as outlined by Sélys in 1854 separated Odonata into Anisoptera (Dragonflies) and Zygoptera (Damselflies) based on the difference in wings (Sandall, 2020) .

The key morphological characteristics of Dragonflies (suborder Anisoptera) are that is characterized by medium-sized to very ,Eyes together, Fore wings & hind wings unequal in size, hind wings broader at the base Strong & robust body ,Wings spread out at rest and Strong agile fliers( figure 3) ,while Zygoptera sub orders that characterized by ,Eyes wide apart ,Fore wings & hind wings approximately of the same size and shape, Slender & fragile body, Wings usually held together dorsally over abdomen and Comparatively weak fliers(figure 4) Carlton et al .,2019).

### *3.5 Data analysis*

Odonata (anisoptera and zygoptera ) relative abundance in the study area was obtained first by combining all of 30 study site records of each sampling transect, to explain variation in odonata assemblages according to the three land use types (agricultural, forest and mosaic land habitats) across the three rivers (Didesa, Gojeb and Gibe River).

Six environmental variables (sunlight, altitude, proportion of cropland, agroforestry, wetland, and forest) were estimated and related to dragonflies and damselflies abundance and distribution using linear regression analyses.

Analyses were carried out using( R) software. The level of significance for all tests was set at $p < 0.05$.

# 4. Results and Discussion

## *4.1 Identification of dragonfly and damselfly to suborder level.*

A total of 958 individuals belonged to 2 sub orders were sampled along the different land use types (agricultural, forest and mosaic dominated watersheds) in the tributers of Didesa, Gojeb and Gibe rivers. Odonata two suborders (Anisoptera And Zygoptera ) were identified during the study period from November 2022 to May 2023 were captured from all thirty sites. Among collected samples total of 425 specimens were identified as Suborder Anisoptera and while 533 was represented with suborder zygoptera (Figure 3 and figure 4).

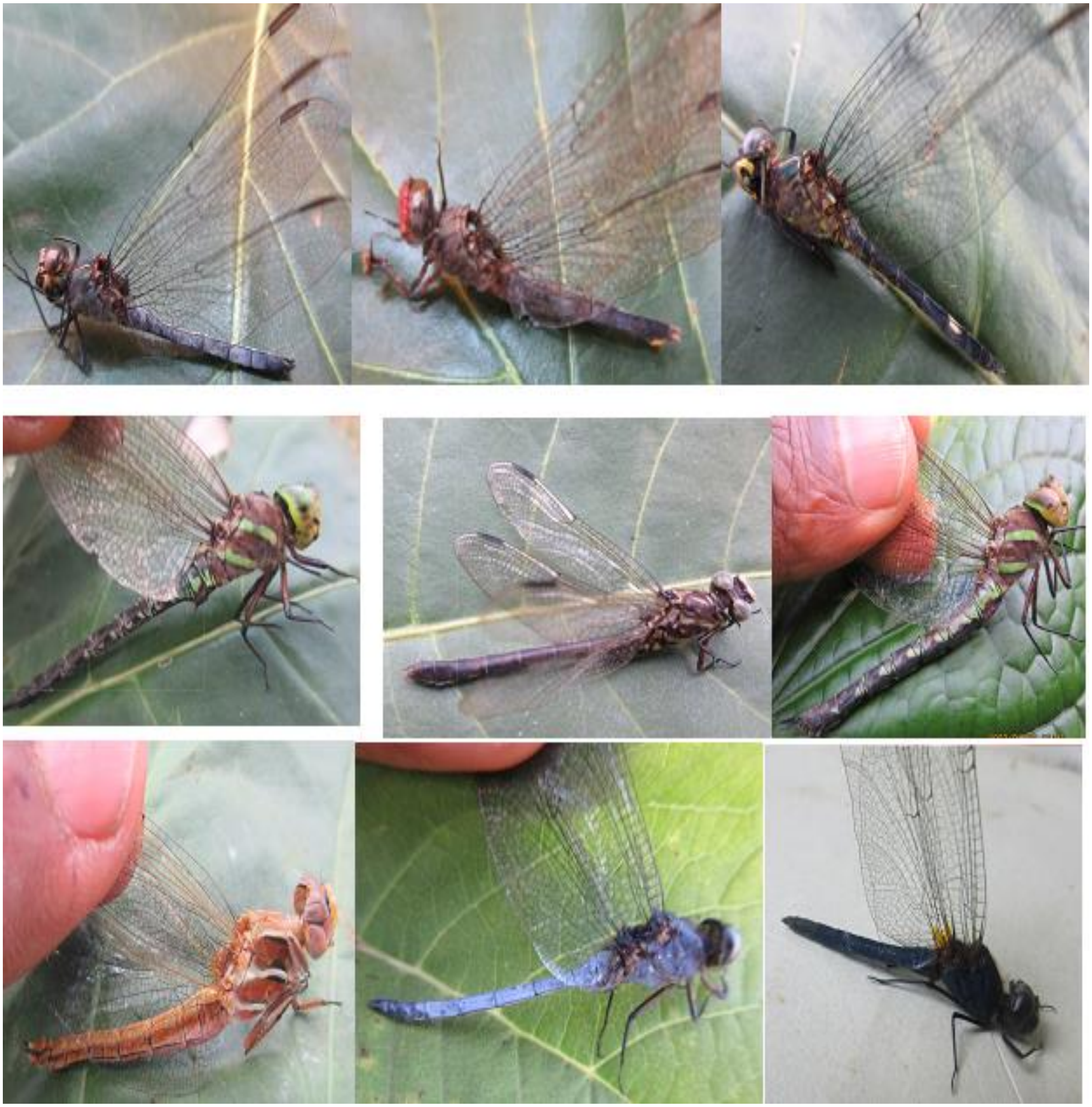


Figure 3 Dragonflies of Suborder Anisoptera from the  31  study site

Figure 4 suborder zygoptera from the 31s tudy sites

## *4.3 Sex proportion*

Female damselflies are distinguished from male damselflies by their club-shaped abdomens, while males appear square-ended. The sex ratio of dragonflies varies, with a high male-biased ratio at breeding habitats. Females use different habitats to avoid harassment, such as wetland habitats and dry meadows. Identifying female dragonflies is challenging, but can be done by combining features like abdomen shape, cerci shape, presence or absence of ovipositor, and abdomen shape. Females have a more camouflaged appearance, with a yellowish or brownish hue.

From the thirty streams male dragonflies accounted for 60% from 425 dragonflies' specimens while 59% male were recorded from 533 damselflies specimens. As indicated in figure 5 ,the dragonflies and damselflies data showed that the proportion of male odonata was higher than that of females (male biased ). In previous studies several authors have argued that the observed and/or estimated male biased sex ratios may be an artefact due to differences in capture probabilities between sexes. Two possible mechanisms may cause sex-linked capture probabilities. First, one of the sexes may be easier to capture. This can be due to differences in secretiveness between sexes or differential attractiveness to traps used for estimating sex ratios.

Second, sexes may differ in their distribution patterns. Because capture mark recapture studies are necessarily limited in space, this may also create differences in recapture probability between the sexes.

Damselflies are relatively well-studied organisms in the context of sexual selection. Several authors have reported on the effects of sex ratio on the mating system and, in general, the reported population sex ratios are male biased, however there is an ongoing controversy about whether these estimated ratios are real. Several authors have argued that sex differences in behavior create artificial male-biased sex ratios and that there are as many males as females in the mature populations. Results from two different field populations confirm the general pattern that observed sex ratios are male biased in mature damselflies populations.

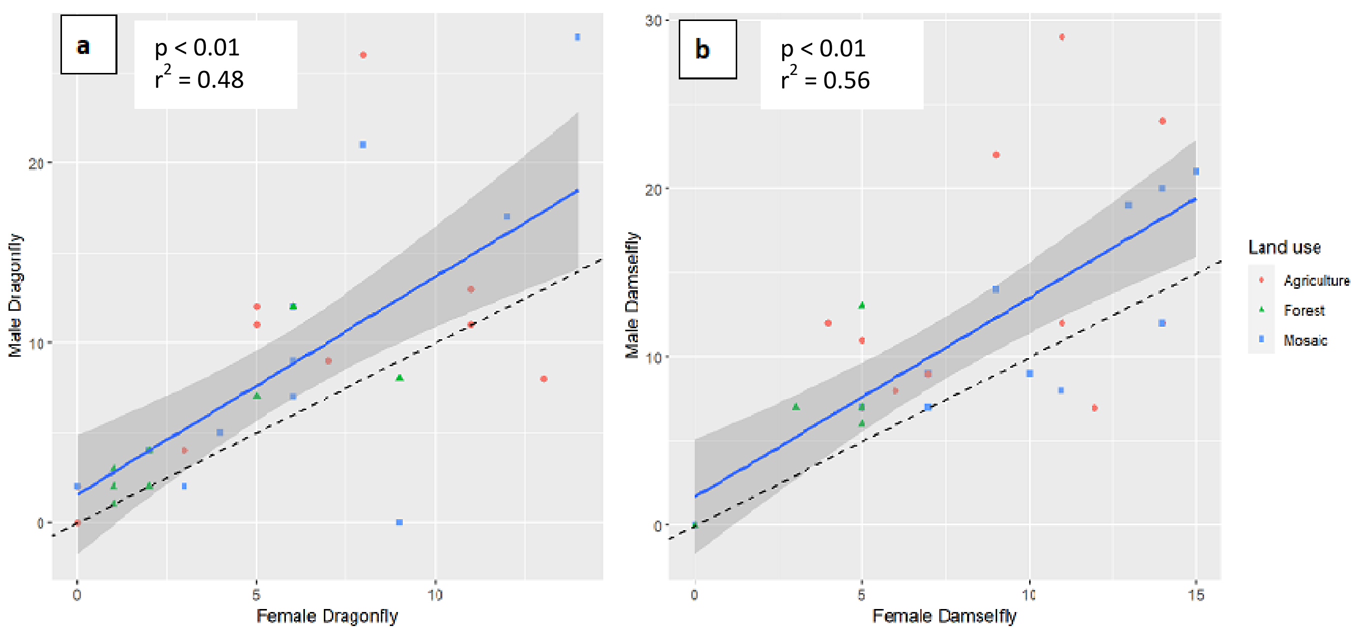



Figure 5 Sex distribution of adult (a) dragonfly and (b) damselfly in three dominant land uses

Table 1  Odonata sex proportion expressed in male to female ratio in different land use

| **Land use** | **df** | **Damselfly (male: female ratio)** | **Dragonfly (male: female ratio)** |
|---|---|---|---|
| | | Mean (%) * | Mean (%) |
| **Forest** | 2 | $31.9^{bc}$ | $60.0^{a}$ |
| **Mosaic** | 2 | $48.9^{ab}$ | $58.1^{a}$ |
| **Agriculture** | 2 | $59.8^{a}$ | $56.9^{a}$ |

*Mean labeled by different letters showed significance difference ($p < 0.05$)

## *4.4 Effect of catchment land use on abundance of odonata suborder*

Catchment land use showed significant effect on the abundance of damselfly but not on the abundance of dragonfly (Figure 6 and figure 7 ). The abundance of damselfly recorded from the mosaic and agricultural dominated catchments were significantly higher ($p <0.001$) than the one recorded in forest dominated catchments. In contrary there is no significant variation ($p>0.05$) among the catchments in the abundance of dragonfly. Stream buffer zone land use influenced the abundance of odonata suborders. Similarly, proportion of wetland in the stream buffer zone favored both damselfly and dragonfly abundance (Figure 5).

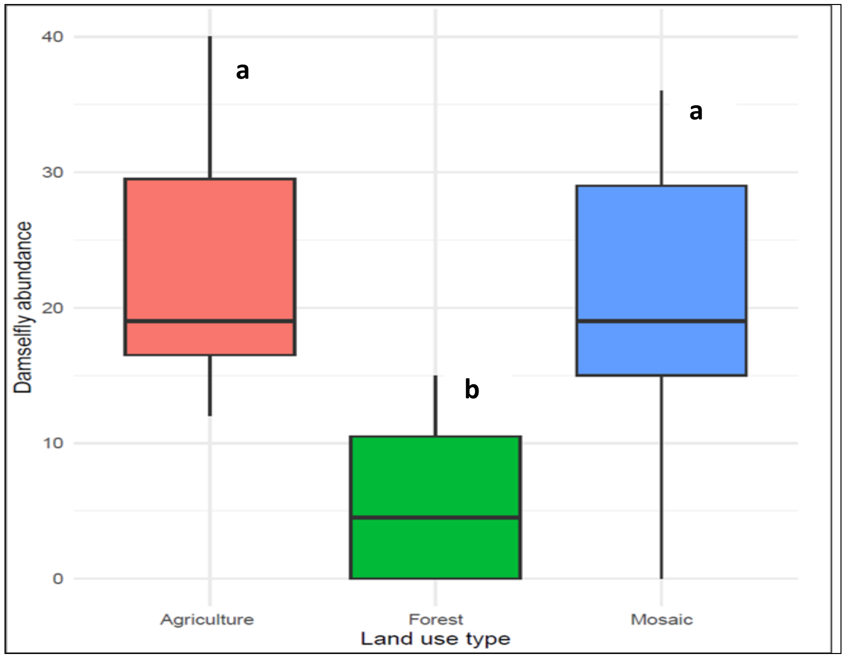



Figure 6 Effect of land use type on damselfly abundance sampled from the tributaries of Didesa, Gojeb and Gibe rivers, Jimma zone, southwest Ethiopia (boxplots labeled by different letters showed significance difference $p < 0.01$)

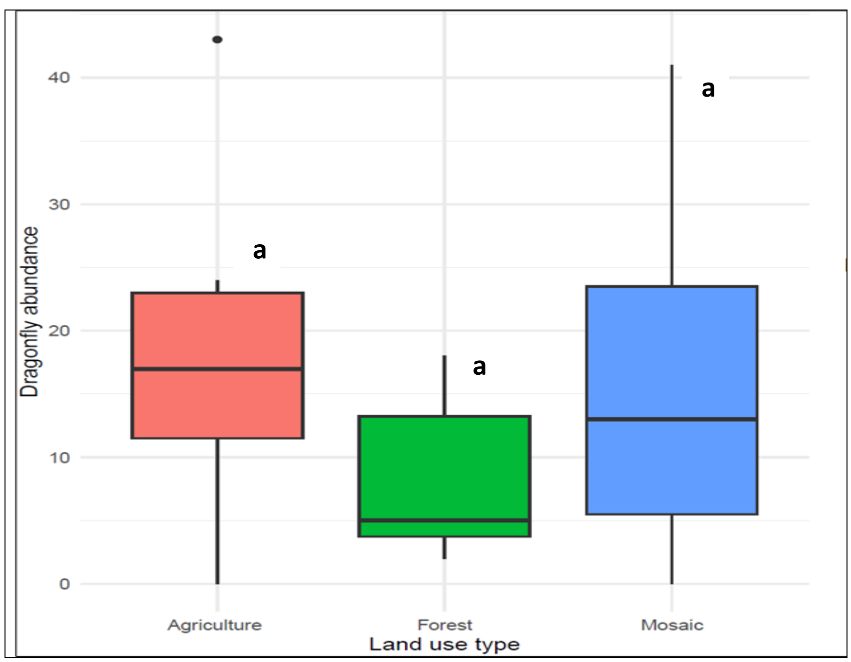



Figure 7 Effect of land use type on damselfly abundance sampled from the tributaries of Didesa, Gojeb and Gibe rivers, Jimma zone, southwest Ethiopia (boxplots labeled by different letters showed significance difference $p < 0.01$)

The distribution and abundance of aquatic insects depend on their sensitivity to pollution or habitat alteration(Kraus and J.M, 2019). In our study site the abundance of damselfly in mosaic and agricultural-dominated catchments was significantly higher than in forest-dominated catchments. This might be due to low sunlight in the stream buffer zone which was influenced by tree canopy shades. Marginal and riparian vegetation, which consists of mixed grasses and sparse growth of pioneer trees and shrubs, significantly reduce the effect of deforestation on the Odonata community (Sommerwerk et al .,2022). Adult odonata are visually oriented hunters with acute eyesight, preferring open and half-shaded areas. The abundance of dragonflies and damselflies was positively affected by the proportion of sunlight in reach (Dijkstra ,2020). Riparian vegetation is a key factor structuring larval odonata assemblages, dictating the quality of aquatic habitats (Cheri et al .,2020).

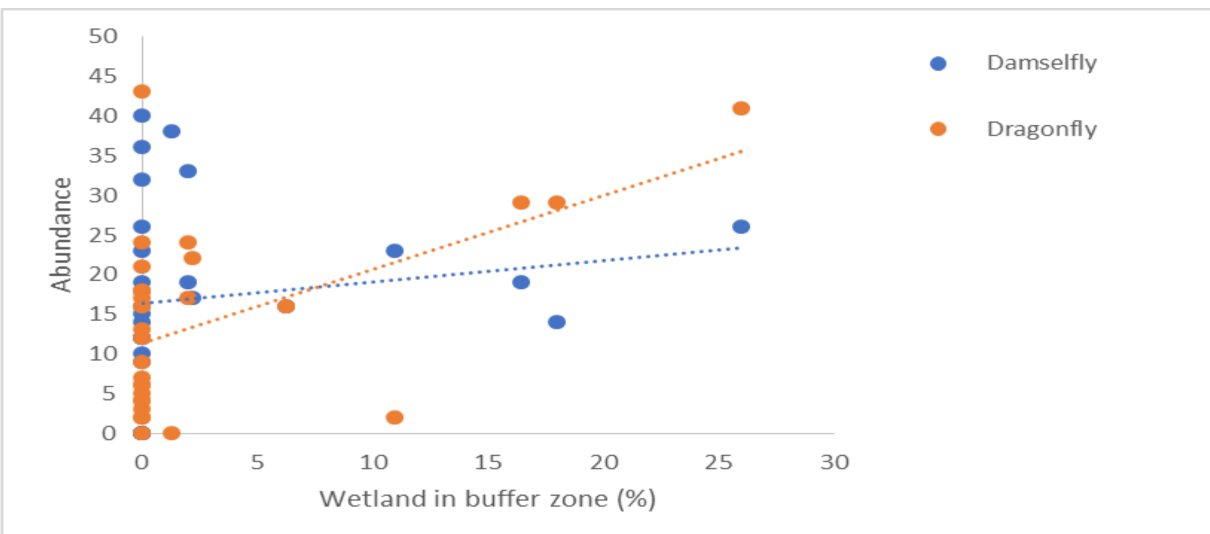
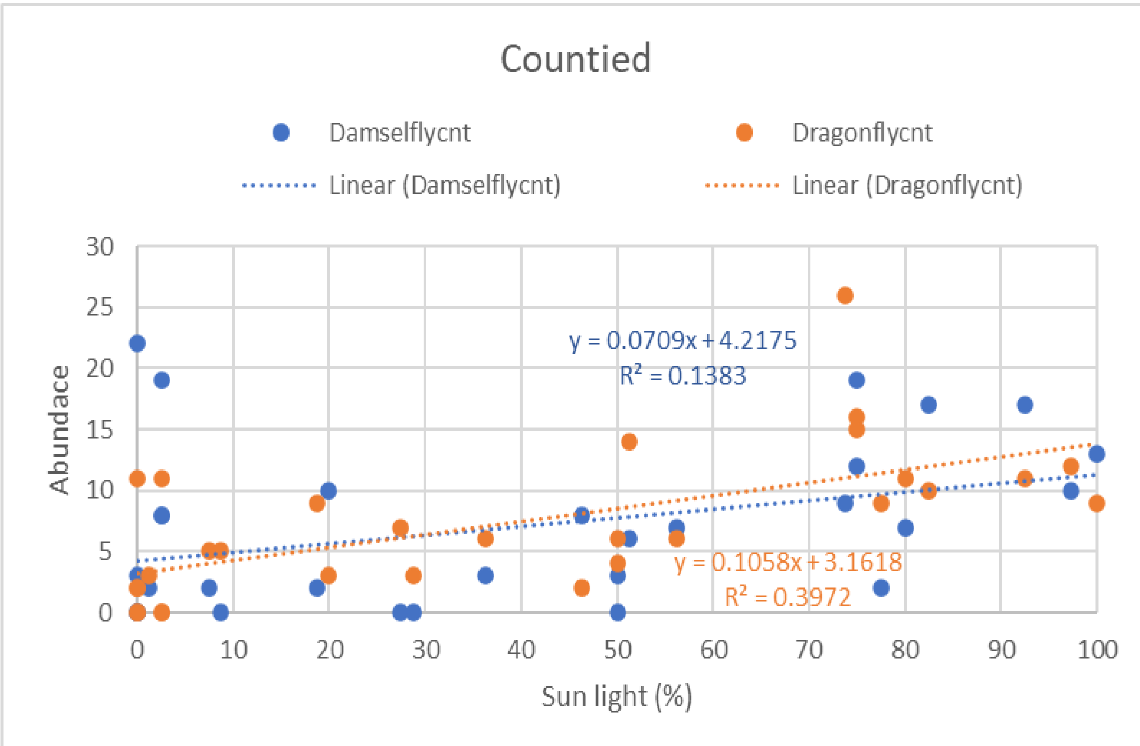



Figure 8 Effect of proportion of wetland in stream buffer on the abundance of dragonfly and damselfly

## 4.5. Effect of sunlight on the abundance of dragonfly and damselfly

The abundance of both dragonfly and damselfly was positively affected by the proportion of sunlight in the reach for both count and sampled (Figure 8). Higher abundance was recorded under higher proportion of sunlight along the streams for both counted and sampled records.

However, the influence of sunlight on the abundance of dragonfly and damselfly varied across catchment land use (Figure 9). Higher proportion of sunlight in the agriculture and the mosaic landscapes favored the abundance of both dragonfly and damselfly while in the forest dominated catchments lower proportion of sunlight limited the abundance of both dragonfly and damselfly below 20 individuals within 100m long reach and 5m wide buffer zone.



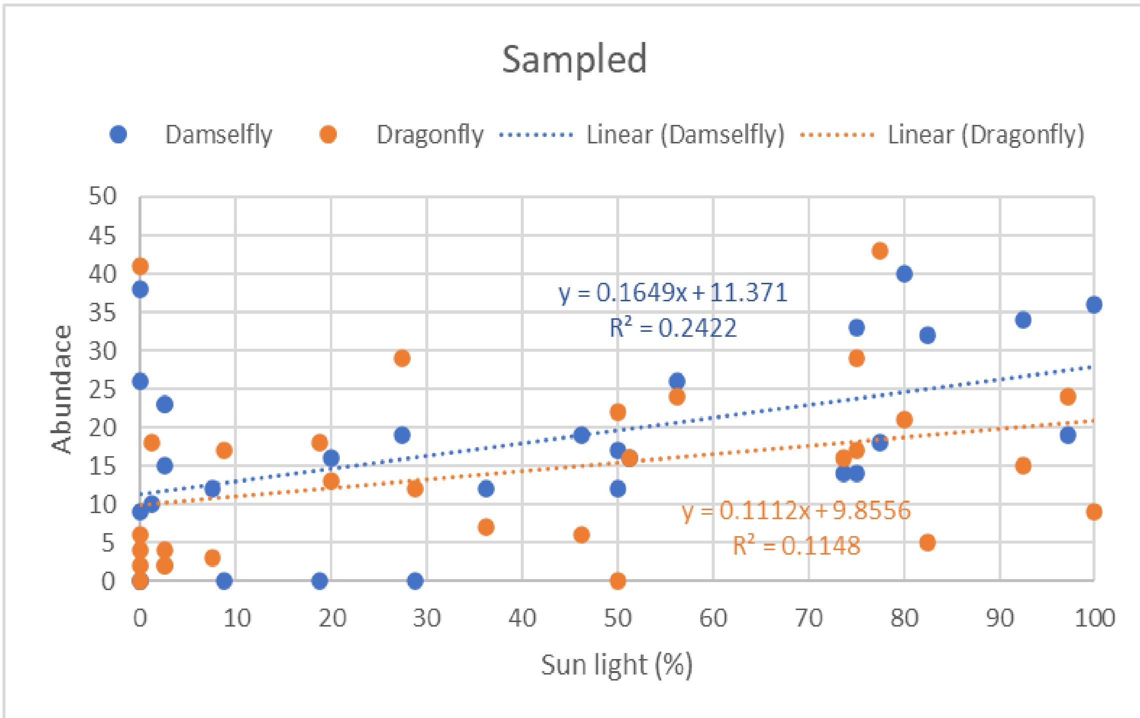



*Figure 8 Effect of sunlight on abundance of odonata suborder (top) counted and (bottom) sampled from the tributaries of Didesa, Gojeb and Gibe Ri vers, Jimma zone, southwest Ethiopia*

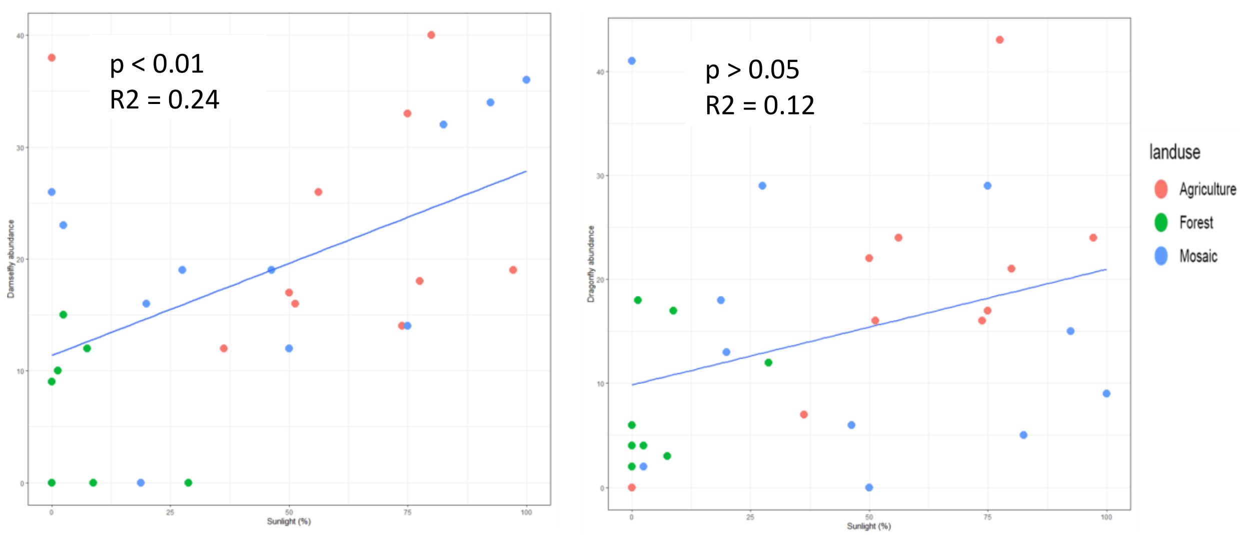



Figure 9 Effect of sunlight on abundance of odonata suborder across three dominant catchment land uses

Similarly, other local condition such as reach altitude is among important factor that influenced the distribution of adult dragonfly and damselflies. In our study site both dragonflies and damselflies showed increasing trends with altitude while higher abundance was recoded within the middle altitude range which is 1700 to 2200 m above sea level in general.

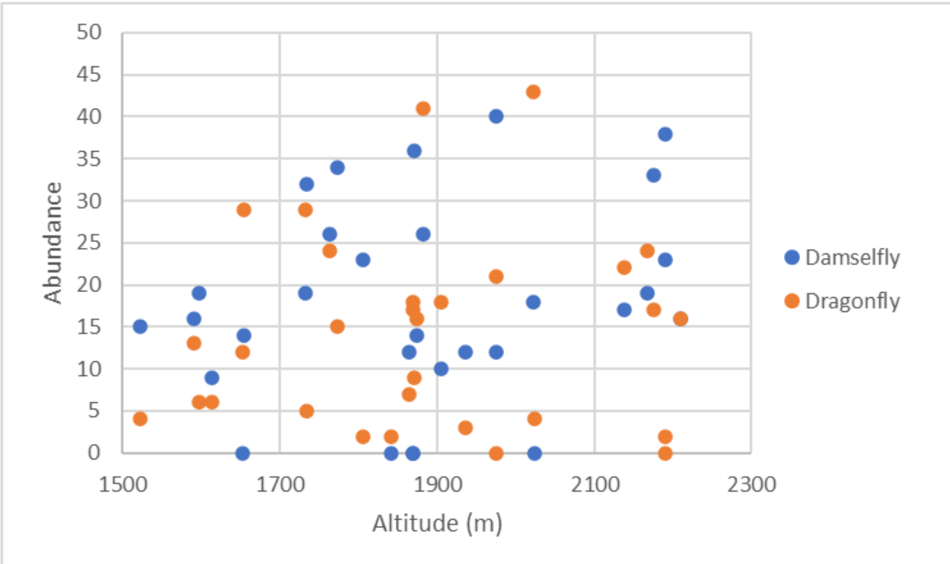



Figure  10 Distirubution of dragonflies and damselflies along altitude

# 5. SUMMARY AND CONCLUSION

Dragonflies are widely used as indicators of freshwater and environmental habitat quality due to their sensitivity to habitat change. Research on odonata responses to ecosystem disturbances is scarce in Ethiopia. Our study sought to determine the impact of human habitat disturbance via land use change on Odonata community structure. Our results show the impact of watershed land use on Odonata abundance (Damselfly and Dragonfly sampled from the tributaries of the Didesa, Gojeb, and Gibe Rivers, Jimma Zone, Southwest Ethiopia. The result showed that the population of both dragonflies and damselflies were male dominated. This might have implication on the reproduction of these group.

Relatively higher abundance of damselflies was recorded in catchments dominated by mosaic and agriculture. However, other local conditions such as proportion of wetland in the stream buffer, altitude and percent of sunlight are among other factors determining the distribution and abundance of both dragonflies and damselflies.

The importance of vegetation in catchment and along stream buffer is crucial in maintaining water quality and habitat condition in general. Although natural forest is important for maintaining water quality, both dragonflies and damselflies preferred open reaches with less shade or more proportion of sunlight reaching stream buffer.

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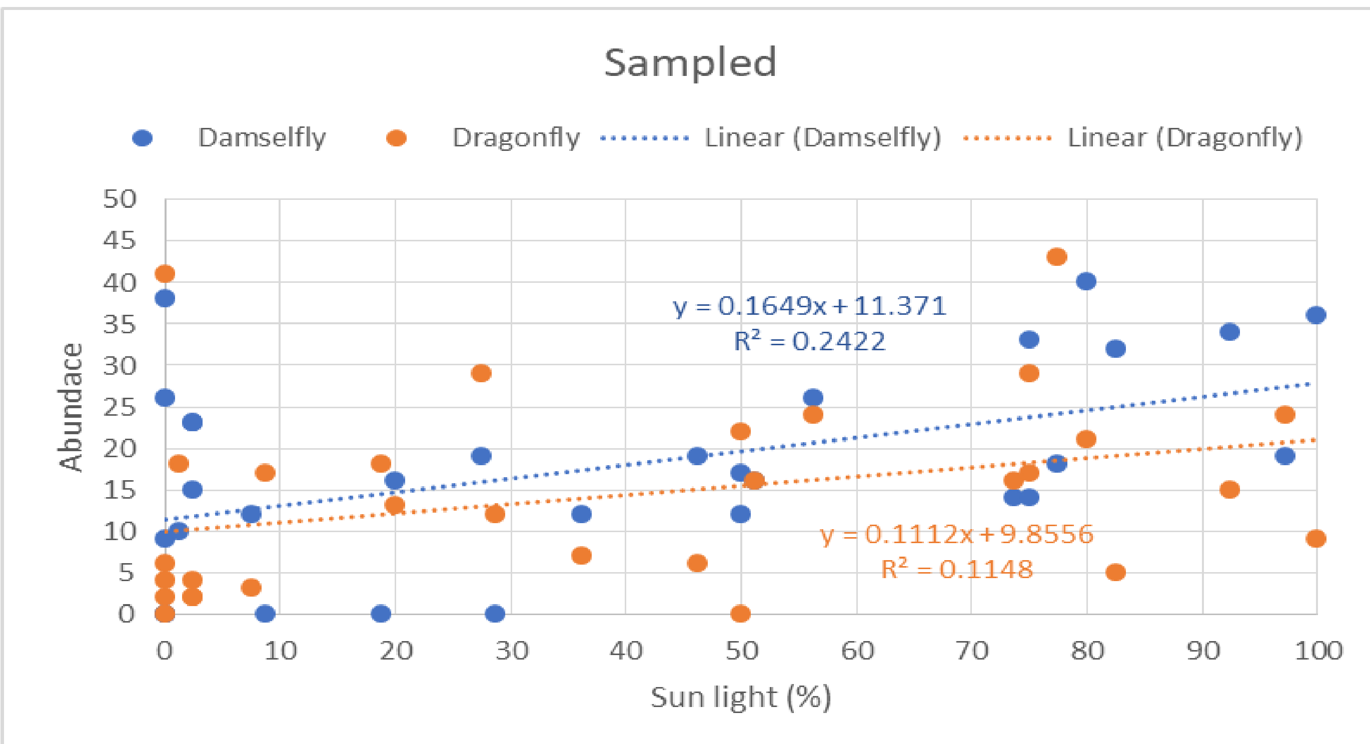
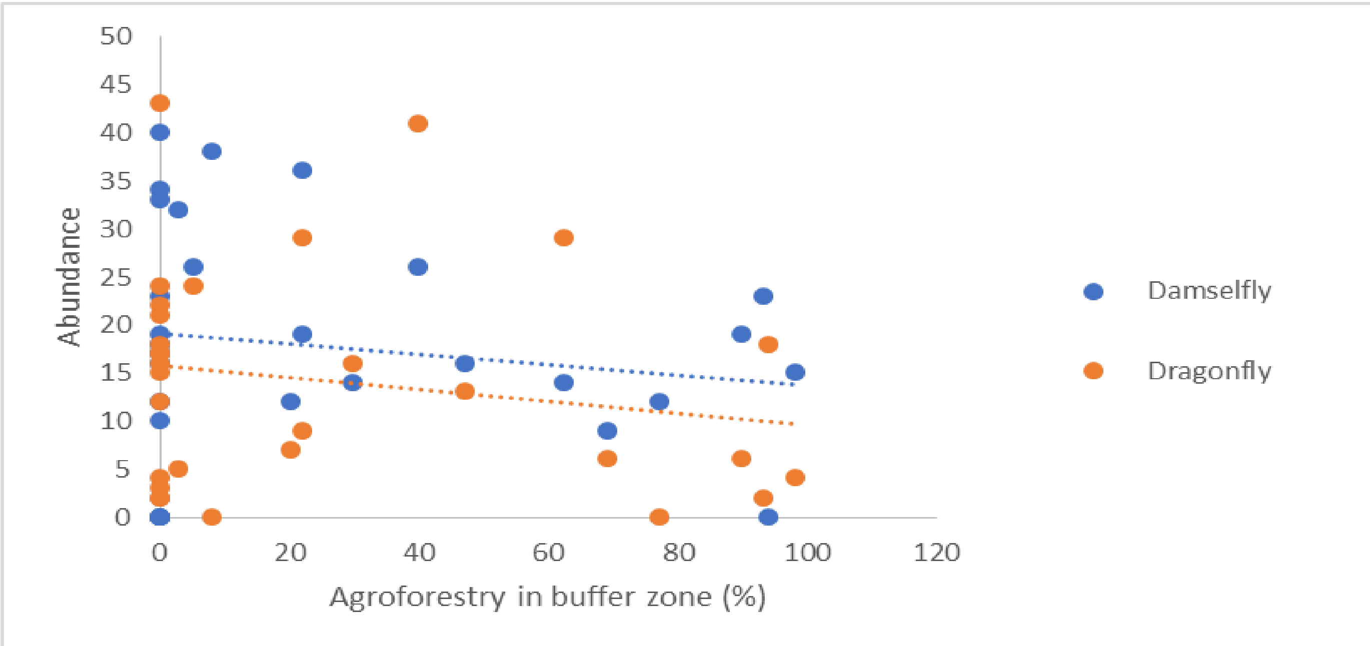
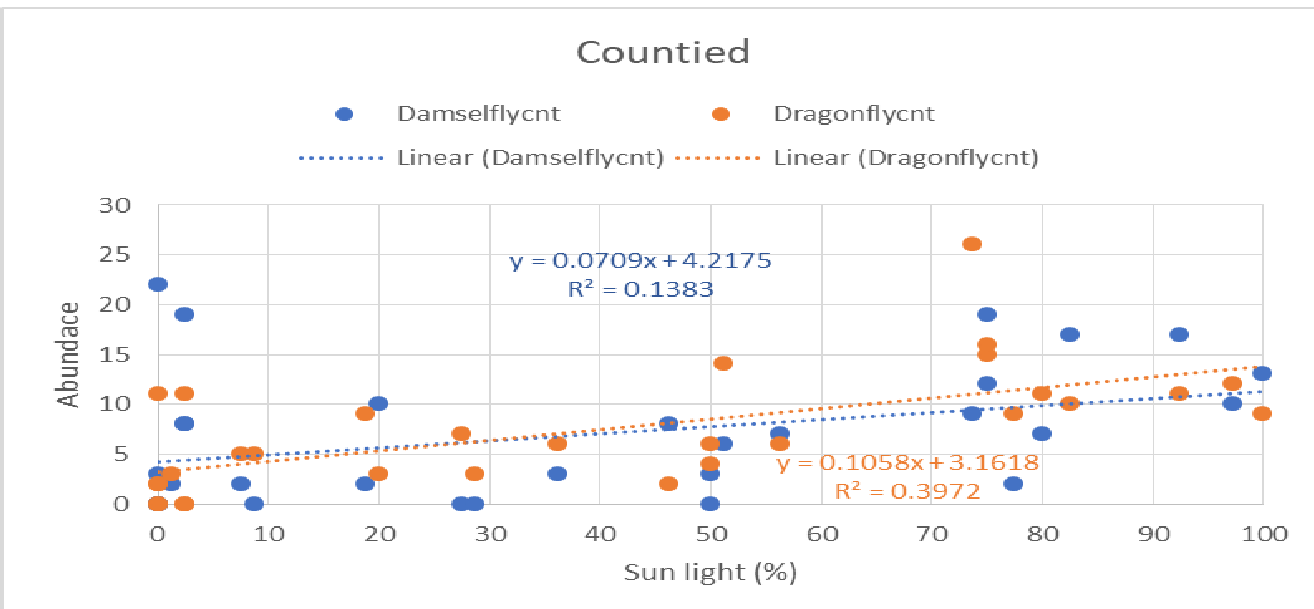
APPENDEX



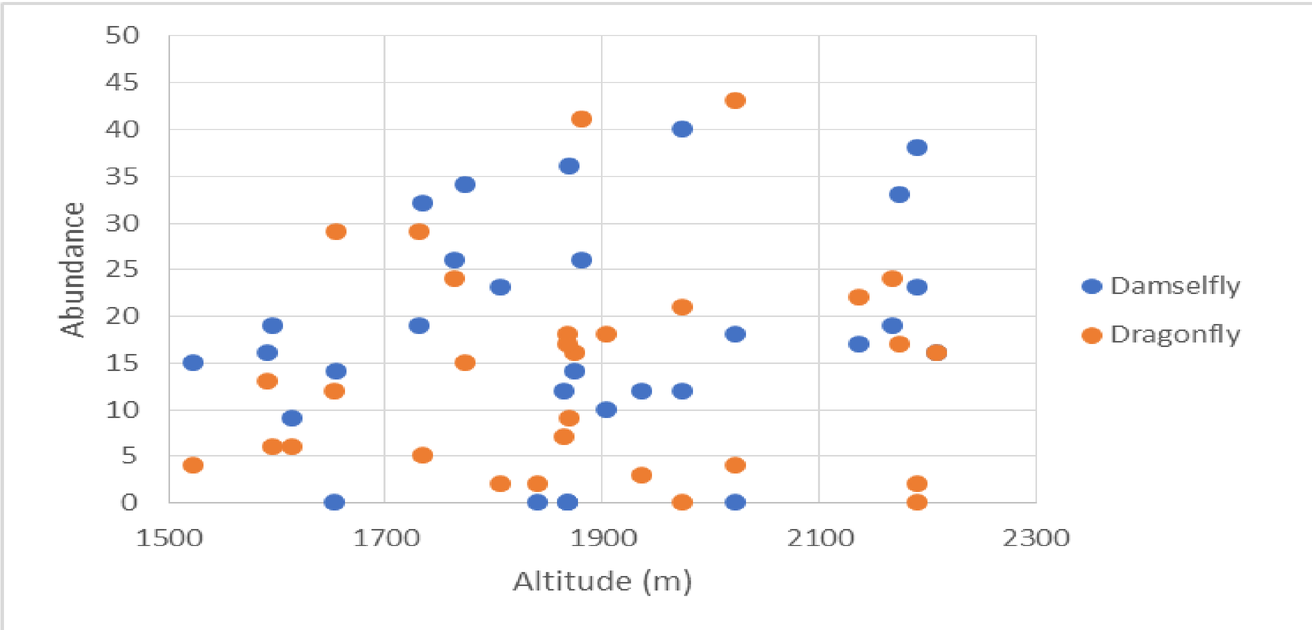
Sampled
Damselfly
Dragonfly
Linear (Damselfly)
Linear (Dragonfly)
y = 0.1649x + 11.371
R² = 0.2422
y = 0.1112x + 9.8556
R² = 0.1148
Abundace
Sun light (%)
0
5
10
15
20
25
30
35
40
45
50
60
70
80
90
100



Abundance
Agroforestry in buffer zone (%)
Damselfly
Dragonfly

Countied
Damselflycnt
Dragonflycnt
Linear (Damselflycnt)
Linear (Dragonflycnt)
Abundace
Sun light (%)
y = 0.0709x + 4.2175
R² = 0.1383
y = 0.1058x + 3.1618
R² = 0.3972



Abundance
50
45
40
35
30
25
20
15
10
5
0
1500
1700
1900
2100
2300
Altitude (m)
Damselfly
Dragonfly