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Soil invertebrates in the Tropics: a bibliographical revision.

Invertebrados terrestres en los trópicos: una revisión bibliográfica.

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ABSTRACT

The invertebrates are the most diverse group in the world; they colonize almost all the ecosystems and certainly give many goods and services to the human beings. The invertebrates that live in the soil contribute consistently with changes in the ecosystemic functions, affecting directly: nutrients, cycle, change in biomass contain ecological nets and inter specific relations for more voluminous organisms. For this exercise were taken the information of the six more representative magazines (2010-2016). The invertebrates in the tropics are maybe the most diverse group, although in the checking stage carried out only 64% represented tropical zones or subtropical exclusively, the rest is a comparison with temperate zones or global studious. Because of its diversity, many invertebrates are waiting for their taxonomical descriptions; many specialists are not from tropical countries. Brazil is the country with more investigations about this theme with its own investigators. No all the invertebrates have received the same attention, and the most studied groups are the orders Hymenoptera (20%), Coleopteran (12%) and Araneae (6%), many families without identification (25%), distinguishing studious in Fomicidae (24%) and Scarabaeinae (8%) mainly. The tendency is to work with those that are better described. The articles selected constitute a key for identifying the most useable methodologies, where the fall trap (30%), quadrant (11%) and transecto (9%), are remarkable over 24 methodologies, the most widespread time of studious was for only one season (< 1 year) the central point of the search in the soil (40%) and the fallen leaves (38%).

KEYWORDS: invertebrates, sampling, soil, tropics.

RESUMEN

Los invertebrados son el grupo más diverso en el mundo, ellos colonizan casi todos los ecosistemas y proveen de muchos bienes y servicios. Los invertebrados que viven en el suelo contribuyen consistentemente a cambios en las funciones ecosistémicas, afectando directamente: ciclaje de nutrientes, cambios en contenido de biomasa, redes ecológicas y relaciones interespecíficas para organismos más voluminosos. Para este ejercicio se tomaron los datos de las seis revistas más representativas (2010-2016). Los invertebrados en los trópicos son talvez el grupo más diverso; aunque en la revisión realizada solo el 64% representó zonas tropicales o subtropicales exclusivamente, siendo el restante una comparación con zonas temperadas o estudios globales. Debido a su diversidad, muchos aún se encuentran a la espera de descripciones taxonómicas, siendo varios de los especialistas oriundos de países no tropicales y teniendo a Brasil como el país que más investigación realiza del tema con investigadores propios. No todos los invertebrados han recibido la misma atención, y los órdenes más estudiados son: *Hymenoptera* (20%), *Coleoptera* (12%) y *Araneae* (6%); varias familias sin identificación (25%), particularizando estudios en *Formicidae* (24%) y *Scarabaeinae* (8%) principalmente. La tendencia es trabajar con aquellos que se encuentran mejor descritos. Los artículos escogidos constituyen una clave para identificar las metodologías más utilizadas, donde las trampas de caída (30%), cuadrantes (11%) y transectos (9%) se destacan sobre otras 24 metodologías. El tiempo de estudio más generalizado se hace por una sola estación (<1 año), centrándose la búsqueda de invertebrados en el suelo (40%) y la hojarasca (38%).

PALABRAS CLAVE: invertebrados, muestreo, suelo, trópicos.

INTRODUCTION

Invertebrates are the most diversified living group in the world, they can colonize almost all ecosystems, and they can certainly provide goods for humans. Because of its abundance, they contribute consistently with changes in the ecosystem functions, directly affecting: nutrient cycling, biomass turnover, ecosystem networks and being the predominant food for many larger organisms. Invertebrates living in the soil contribute to the above stated processes, these organisms, although resilient to small changes that are naturally occurring in their surroundings; can dramatically shift the number of individuals (abundance) and the amount of species (diversity/richness) if the change that they face has large consequences within their distributional home range. The invertebrate responses to these land use changes, that affect soil invertebrate fauna, have been studied to find answers about the degree of diversity/abundance lost. Invertebrate behavior can also represent stages that are common in the process of ecosystem alteration. Therefore, soil invertebrates have been considered as ecological bioindicators in the process of ecosystem restoration.

Soil invertebrates in the tropics are perhaps the most diverse in the globe. However, because of its diversity, a great amount of them are still waiting for formal taxonomic classification, and most researchers work with morpho-species or higher taxa levels (when explaining biodiversity). Not all taxa have received the same attention, and the tendency is to work with the groups that are best described. Furthermore, taxonomic specialists are not alwayspresent in tropical countries, increasing the difficulty to work with lower descriptions.

In that regard, to recognize the main ideas researched abouttropical soil invertebrates in the last six years (2011-2016), a selection was made of the most representative journals in: ecology, soil, the tropics, forest conservation and invertebrates.

METHODOLOGY

We organized a search in the online data base of the libraries from the University of Toronto. In the search, we used the key words: community ecology, conservation, tropical, invertebrates, and soil to narrow down the items related with tropical soil invertebrates. Those key words were analyzed in journals that reflected representative studies in: ecology (Ecology journal), soil (Applied soil ecology and Soil biology and Biochemistry), tropical studies (Biotropica), forest and conservation (Forest ecology and management, Biological conservation), and invertebrates (Journal of insect conservation). If the climatic region was not clearly stated in the methodology, the location of the study was used to classify the place based on a regional categorization of Köppen climate *(Kottek, et al*., 2006).

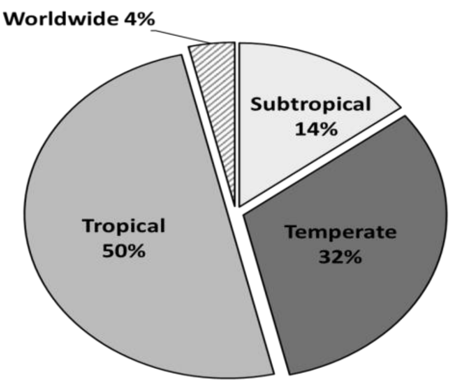
The search focused on the major ecosystems studied (1), the main studied groups (2), the methodologies used for invertebrate sampling (3), the amount of time spent in every research (3), the origin of the institutions doing research in the tropics (5), their names (6) and the names of their researchers (7). Finally, the main topics of invertebrate study (8) in the tropics were summarized and discussed out of a sample of 83 articles. All results were summarized in percentages. We considered: sampling methodology, invertebrate group (up to 13, after that number they were considered as various), research institutions, countries and researchers; as one count for the final percentage.

RESULTS

Climatic regions

The most influencing journal in the search was the Journal of Insect Conservation. The journal provided 41% of the articles for this analysis. Most of the search was predominant for tropical or subtropical environments (63%). However, even when “tropical” was included as a key word in the search engine, 32% of the articles were (26) done or compared with temperate regions. Four percent of the articles provided worldwide reviews on bioindicators, and spider activity (figure 1).

Figure 1. *Climatic regions covered by the most important publications of seven journals published between 2011 and 2016.*



Source: *Prepared by the author.*

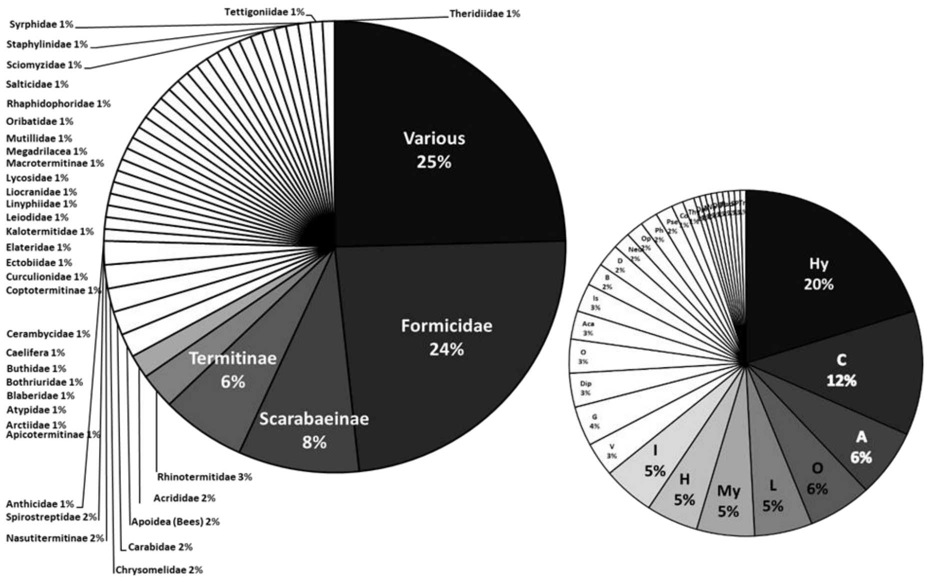
Seventy-seven percent of the articles provided information of invertebrates from natural ecosystems. More than half of the studies were performed in forested ecosystems, 6% in steppe ecosystems, 8% in savannas and 6% in other ecosystems. An important 23% of the investigations were conducted under managed ecosystems, where grasslands occupied 13% of all the studies, 1% the cities and 10% to other type of managed ecosystems.

The main groups of invertebrates under study

The mainorders (68%) described by the studies are: Hymenoptera (20%), Coleoptera (12%), Araneae (6%), Orthoptera (6%), Lepidoptera (5%), Hemiptera (5%), Isoptera (5%); the class Myriapoda (5%) and the studies that combined various (more than 13) orders with 4% of representation. It was assumed that articles which worked just at the order level included several families (various).

At the family level, non-categorized families (or those greater than 13) had the highest percentage (25%) in the evaluated articles. Formicidae followed the amount of representation with 24%, the subfamily Scarabaeinae had 8% of the studies and the last major representative was Termitinae with 6% (figure 2).

Figure 2. *Orders (right) and Families (left) of soil invertebrates analyzed in the most important publications of seven journals, published between 2011 and 2016.*



Note: Hy=Hymenoptera; C=Coleoptera; A=Araneae; O=Orthoptera; L=Lepidoptera; My=Myriapoda; H=Hemiptera; I=Isopoda; V=Various. **Source:** *Prepared by the author.*

It is interesting to note that, while at the order most of the papers recognized most of the groups that they were working with (Various 4%). At the family level the percentages flipped, and the groups that were not recognized (or very abundant) comprised 26% of the description. It is also worth to mention that the whole Hymenopterans represented 20% of the studied orders, but in the family level those were represented mainly by Formicidae studies (23%).

Time and Methodologies used for invertebrate sampling

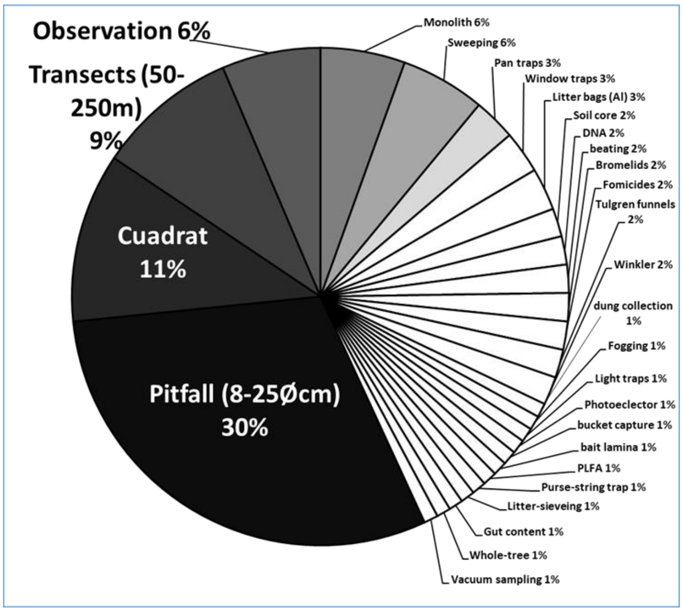
Most of the studies collected the data in one season of insect trapping and identification (<1 year for 62%). One year of trapping, or the comparison of at list two years for the same season was achieved by 20% of the articles (1 year). Two years of measurements were performed by 9% of the studies. The remaining 9% of the studies collected data from 3 to 11 years.

There was a great wealth in the methodologies used to sample the invertebrates (figure 3). They mainly depended on the intention of the research. If the research were to described land use management, very specific sampling methodologies were applied. However, there were a few methodologies preferred over others. Thirty percent of the articles set pitfall traps, mostly relating them with studies of biodiversity and bioremediation. The quadrat methodology (3 m^2 to 10 m^2), a epigenous survey of all the invertebrates in the soil (sometimes also considering shrubs), was used in 11% of the investigations. Transects (50 m to 250 m with 1 or 2 m in width) were used in 9% of the studies, mainly in combination with other sampling methodologies. Pure observation of the researcher surroundings was used in 6% of the cases. Observation usually was done when the study involved multitaxon analysis.

Curiously, the monolith sampling methodology, which is the standard methodology recommended for tropical environments was used only in 5% of the cases. The monolith methodology requires to dig a square of 25 cm by 25 cm at a 30 cm depth and account all the invertebrates that can be counted in that soil volume.

Pan traps, window traps and sweeping nets were used in combination with other methodologies for soil invertebrate capture, accounting for 11% of the sampling methodologies used in the experiments. The 30% left used different methodologies depending on particular land uses types or specific insect determination (figure 3).

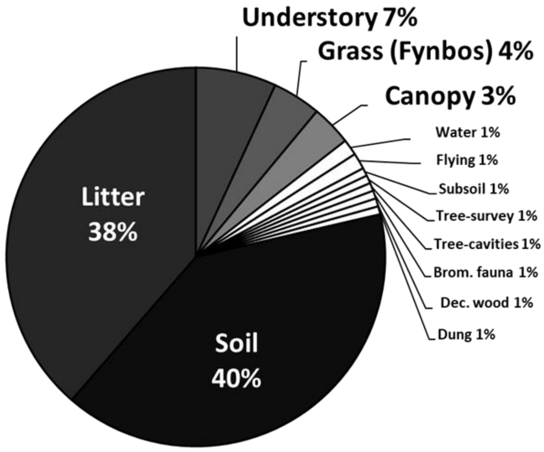
Figure 3. *Methodologies of soil invertebrate analysis of the most important publications of seven journals, published between 2011 and 2016.*



Source: *Prepared by the author.*

The methodologies explained above surveyed insects mainly from the soil and soil litter (in 78% of the cases), and the interaction between dung and soil (1%). Other methodologies that considered a wider vertical spectrum of the samplings comprised 13% of the studies (understory, grass, tree survey, and decaying wood). Canopy invertebrates were analyzed in 3% of the cases, always in a relationship with soil/litter organisms. Flying insects were analyzed in 1% of the studies. Very peculiar ecosystems were analyzed for the rest of the studies, they focused on the interphase between riparian environments and the insects that interact with the soil (1%), tree cavity diversity in comparison with soil diversity, and bromelids. The last experimental unit considered the whole living organism as a unit to measure the abundance and diversity of invertebrates, relating their existence with general biodiversity patterns and management quality (figure 4).

Figure 4. *Specific location of the insect sampling in the most important publications of seven journals published between 2011 and 2016.*



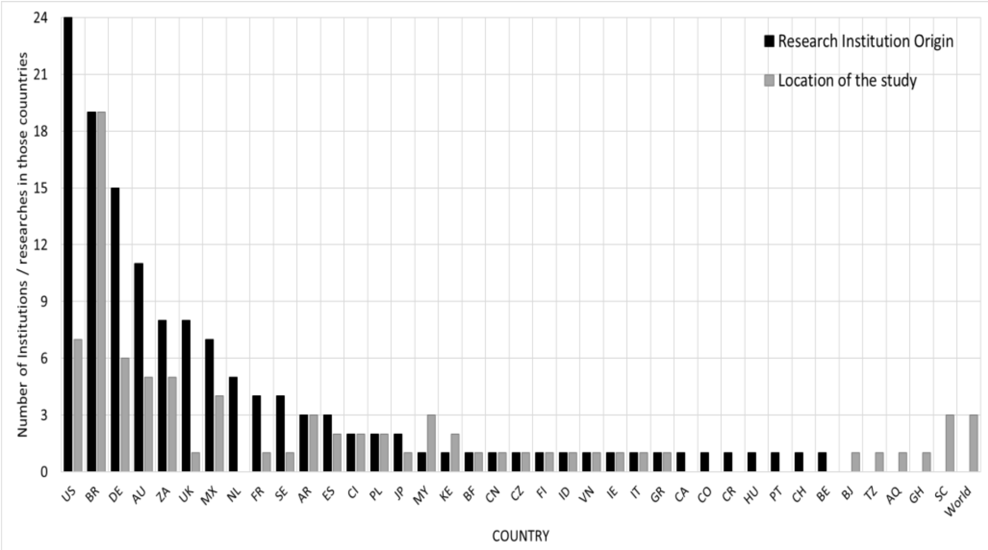
Source: *Prepared by the author.*

Origin of the institutions that do research in the tropics

In most of the cases the countries were the research was performed was also the place for the research institutions. However, in four countries (Benin, Tanzania, Ghana, and Seychelles Islands) the research had no national representatives in the published articles. Sixty-six percent of the research took place in tropical and subtropical countries, and 10% was done in countries that contain such regions (Puerto Rico, Hawaii, South China).

The countries with expertise in invertebrates (based on the survey) are: United States, Brazil, Germany, Australia, South Africa, United Kingdom, Mexico and The Netherlands. The Netherlands had five institutions collaborating with the study of invertebrates in tropical regions, and all the others had more institutions. From 179 institutions, Public Universities and research centers are the most prevalent institutions studying on invertebrates, yetnon-governmental agencies from various countries (Fundación para el Estudio de Especies Invasivas -Argentina-, the Earthwatch Institute-UK-, as well as Advanced Conservation Strategies, Island Conservation, The Conservation Land Trust Argentina from US) and a private (Canopy Access Ltd. -Australia, UK-) institution was also recorder as part of the analyzed research. Stellenbosch University from South Africa collaborated in eight studies, mainly located in the Seychelles Islands. The University of Würzburg, from Germany, was present in six studies, partnering with Kenyan and Brazilian institutions. The research center INPA -Brazil-, SCIRO -Australia- and the University of Göttingen -Germany- participated in five publications each. With four publications, I found institutions from Mexico (Instituto de Ecologia), the UK (Lancaster University) and Brazil (Federal Universities of Lavras and Viçosa). The rest of the institutions had three or less publications.

Figure 5. *Countries that perform invertebrate research, and those where this research is performed (circle inside) in the most important publications of seven journals, published between 2011 and 2016.*



Note: US=United States; BR=Brazil; DE=Germany; AU=Australia; ZA=South Africa; UK=United Kingdom; MX=Mexico; NL=The Netherlands; FR=France; SE=Sweeden; AR=Argentina; ES=Spain; CI=Ivory Coast; PL=Poland; JP=Japan; MY=Malaysia; KE=Kenya; BF=Burkina Faso; CN=China; CZ= Czech Republic; FI=Finland; ID=Indonesia; VN=Vietnam; IE= Ireland; IT=Italy; GR=Greece; CA=Canada; CO=Colombia; CR=Costa Rica; HU=Hungary; PT=Portugal; CH= Switzerland; BE=Belgium; BJ=Benin; TZ=Tanzania; AQ=Antartic; GH=Ghana; SC=Seychelles Islands. The circle inside includes only locations of study: in black the tropical and subtropical countries, in grey the countries with tropical subtropical and temperate studies.
Source: *Prepared by the author.*

Michael J. Samways, from Stellenbosch University, was the most mentioned researcher (6 items), followed by Jos Barlow from Lancaster University (4 items). Jörg Müller (University of Würzburg), Julio Louzada (Universidade Federal de Lavras) and Ricardo R. C. Solar (Universidade Federal de Minas Gerais) had three publications each one. All other 368 researchers had participated with in two or less pulbications.

Main topics of invertebrate study

The papers addressed four major areas. At first biodiversity and its relationship with the need to increase our knowledge about the most abundant animal guild (Arthropods). The articles analyzing this issue described beta diversity in most of the cases. They also focused on spatial diversity and the importance of microhabitats existence for the persistence of diversity as such. Biodiversity was also seen as multiversities that included various types of communities stating that a multitaxa analysis enriches the assessment of biodiversity conservation. Once recognized the importance of diversity. The species links among invertebrates and other taxa were also remarked (second). A main idea of the importance of invertebrates in the ecosystem functioning was stated. The importance of the invertebrates in the process of nutrient cycling was described specially for those that feed on earth or facilitate litter turnover. Those processes are in place when networks of different functional groups are harmoniously coexisting. These processes can resist certain external (invasions, land use change, pollution) pressure after which they collapse, generating a disturbance that breaks the natural fluctuation of the particular soil environment.

The third main parameter evaluated was the use of insects as bioindicators, focusing on the importance of ecosystems health and the constant monitoring of this state through groups of invertebrates (and other taxa), which are sensitive to environmental changes. The identification of these groups reinforces the decision making in processes of ecosystem remediation and restoration. Finally, they proposed various alternatives to measure the impacts caused by environmental disturbances. The alternatives were based on the study of particular invertebrate responses to specific changes (pollution, deforestation, city transformation of environmental patterns), as well as alternatives of multitaxon inclusion to sustain and improve the health of the ecosystems (agroecology, sylvopastoral systems, directed regeneration).

DISCUSSION

Species identification

The studies detailed their research subjects down to genus or species when it was related to biodiversity conservation as in the case of: Orthopteran sensitiveness for fynbos ecosystems in South Africa (Matenaar *et al.* 2015), the conservation of millipedes (Lawrence *et al*., 2013a, 2013b) and invasive ant suppression (Gaigher & Samways, 2013) in the Seychelles Islands. The biodiversity loss at genus or species level was also studied in Formicidae and other taxa due to land use change, from forest to pastureland in the Amazon (Solar *et al*., 2016), the loss of bees and wasp in Germany (Krewenka, Holzschuh, Tscharntke & Dormann, 2011), and the conservation status of spiders in Central Europe related withgrazing (Řezáč & Heneberg, 2014). City expansion was causing bee declinein Poland (Banaszak-Cibicka & Zmihorski, 2012), and invasive ants in Kenya diminished local fauna (Peters *et al*., 2013).The biodiversity assessment was also used to enhance the species characterization, as for: predatory ants (Tillberg *et al*., 2014) and scorpions (Nime *et al.,* 2014) in Argentina. It also serve to refine the sampling of canopy ants in Malaysia (Yusah *et al*., 2012), and ground beetles in Poland (Zmihorski *et al.* 2013). Biodiversity studies were also used to explored the invertebrate diversity of troglobionts in Spain (Jiménez-Valverde *et al*., 2015) and the difference in the acari assemblage of tree hollows and soil in Sweeden (Taylor & Ranius, 2014).

Velvet ants show a particular diversity response to deforestation; they decrease in abundance as canopy closes inside Amazonian forests (Vieira *et al.,* 2015). Termites showed significant increases in diversity in forested ecosystems while decreased in managed agricultural lands of Benin (Hausberger & Korb, 2016). In dunes, although not significant, ant also decreased in number as bushes recover coastal dunes in United States (US), but their diversity increased showing unique ant assemblages in the (less degraded) bushes area (Chen *et al*., 2014).

Mutualistic mechanisms where also studied at the species level in the ant-plant relationship for plant gain in defense against other herbivores (Pringle *et al.,* 2011), plant gain on seed dispersal (Lima *et al.,* 2013) and the increase of savanna destruction when the plant-ant symbiotic relationship decreased (Riginos *et al*., 2015) all the above studies were performed in tropical ecosystems. Even when, the ant-plant can have posstitive effects for the habitat were ants and plants interact, invasive ants show negative effects in the environment as it was shown in the Seychelles Islands (Gaigher & Samways, 2013), they can also reduce diversity by habitat monopolization (of yellow crazy ants) as shown in Malaysia (Drescher *et al.*, 2011). In a global analysis the most prominent invasive ants seemed to had: *Anoplolepis gracilipes* and *Pheidole megacephala*as winners for invasive potential (Hoffmann *et al*., 2016).

Nutrient cycling is another issue analyzed at the species level. In Hawaii using snails in tropical ecosystems it was possible to estimate the rate at which mollusk make possible biomass turnover (Meyer *et al.,* 2013), . Nutrient cycling was also examined in Coleopterans that importantly increased dung decomposition in Finland (Kaartinen *et al*., 2013). Nutrient-and-energy-flow ecosystem dynamics were assessed by the parasitic behavior of nematomorphs inside grasshoppers in Japan, finding big changes in energy flow (Sato *et al*., 2011). As in grasshoppers, a different multitaxa analysis showed ant reduction(abundance and richness) with overall forest loss in the Amazon (Morante-Filho *et al*., 2016). Ecosystem services of organic matter decomposition, assessed at the species level, decreased together with the diversity of ants in a gradient of cocoa plantations with natural and pesticide management in Ivory Coast (Kone *et al.*, 2014). Kone found that the area without management in agricultural lands is vital for biodiversity interests. This result was also indicated by Formicidae in Australian agricultural lands (Hoffmann *et al*., 2016). Finally, Termites show responses to agricultural land uses. They seem to be directly influenced by litter depth and bulk density in Vietnamese environments (Neoh *et al*., 2015).

There is a comprehensive index of soil invertebrates used to correlate the impact of soil physical and chemical properties on different land use types in France. This study works with the identified species found throughout French land use types. This effort provides a tool for decision making based on the amount of invertebrates and the diversity present at various landscapes (Ruiz *et al*., 2011). This work has been sustained in the research previously made in Tropical countries (Colombia and Nicaragua), were a General Indicator of Soil Quality was idealized based on macrofauna coupled with environmental conditions. These parameters allowed to generate the idea of a comprehensive index for soil analysis in various tropical land use types (Velásquez *et al.,* 2007).

Even when, most of the studies started with a multitude of taxa, they did not go below family to explain their results for most of them, choosing particular families or genus for species identification (except for Ruiz *et al*., 2011). The behavior that different invertebrates presented at the species level would consistently explain the relationships with functional invertebrate groups (Ruiz *et al.*, 2011; Velásquez *et al*., 2007). But the lack of proper alfa taxonomical descriptions still decelerate a better understanding of the invertebrate world (Gerlach *et al.,* 2013)

Family identification

Biodiversity at the family level has been analyzed the role of latitudinal variation of various termites in the Atlantic forest of Brazil (Cancello *et al.,* 2014). With family identification, global patterns showed the importance of dead wood on the biodiversity (Seibold *et al*., 2015). It has also helped to analyze the temporal variation of spider assemblages in China (Schuldt *et al.*, 2012), termites and earthworms in Burkina Faso (Zida *et al.*, 2011); identifying changes in functional structure. Ant families have illustrated the recovery of Mexican forests, comparing the increase of ant richness in a forest recovery gradient (Rocha-Ortega & Favila, 2013).Moreover, family analysis has also shown the importance of replacing vegetation (invasive) on diversity maintenance of South African savannas (Van der Colff *et al.*, 2015). The ecosystem length of Coleoptera has been also measured for Australian environments. Savanna and forest beetles were distinctly different; but within savannas, the length of the region also created especial patterns among ant species (Barton *et al.*, 2013).

Fire was the most present subject when studying insect assemblage at this identification level. Recurrent fires seem to have short (3 to 5 years) term effects in ant diversity on the Amazon (Silveira *et al*., 2016) and community composition in Australia (Wittkuhn *et al*., 2011), where they are recommended for monitoring of prescribed burning (Beaumont *et al.* 2012). Savannas from the United States have also predominant opportunistic ants in burned trails when compared with non-burn trails (Moranz *et al*., 2013). However, Argentinian researchers said that ants are not reliable as fire bioindicators, unless they are used in bioremediation (Calcaterra *et al*., 2014). Another invertebrate subfamily, Scarabaeinae, have important variations in assemblage over time after various fires (Silveira *et al*., 2016). In that case, large bodied beetles were negatively impacted by fire events, having environmental alterations on biomass content and ecosystem nutrient cycling in Amazonian forests (de Andrade *et al*., 2014). In South Africa savannas, with short term recovery (3 years, in most of the cases), butterflies, ants and Scarabaeinae beetles were recommended as taxa to be used in arthropod monitoring for fire-recovery in conservation programs (Pryke & Samways, 2012). The spatial changes in forest burns are also important for Coleopteran abundance, while temporal variations might influence also lepidopteran at list after two years in Mediterranean Forests (Elia *et al.*, 2012).

Litter is one of the factors that heavily shape insect assemblages at the family level. When litter,in Indonesia,decreases due to agriculture (oil palm to natural forest gradient) insects dramatically dropped their numbers (Mumme *et al.*, 2015). In South Africa litter input and litter-dependent invertebrates (Termitidae) are also affected by mammal grazing and seasonality (Gosling *et al.*, 2016). Invertebrate predators (ants) have also huge effects on litter decomposition, when they eat scavengers (Ectobiidae/Blaberidae)(Tarli *et al*., 2014) and other debry eaters (Termitidae) in Amazonian environments (Dambros *et al.*, 2016). The change in edge ecosystems also affects the amount of litter and dung present in it. Dung beetles were more diverse inside Cerrado ecosystems than open areas or agricultural lands in Brazil (Martello *et al.*, 2016), resembling the same outcomes seen in velvet ant abundance (Vieira *et al.,* 2015).

Beta diversity can be analyzed in various soil use types. Earthworms and ants are more diverse in managed lands with *Arachis pintoi*, when compared with other Amazonian cultivated grasses (Velásquez *et al*., 2012). Also, Ant-bromelid biodiversity decreased with homogenization (less tree cover) of cocoa plantations in the Amazon (DaRocha *et al.*, 2016), even when they are not considered as specialist bromeliad community (Richardson *et al.,* 2015). It was observed in mango orchards of Ivory coast, that Termites had similar assemblage in 30 years old orchards and natural savanna ecosystems, while new orchards were lacking on Rhinotermitinae and Cubitermitinae subfamilies (Coulibaly *et al*., 2016). Additionally, canopy-ants were found to have clear variations when present in arsenic contaminated sites, whereas soil ants presented less sensibility to the contaminant in Brazil (Ribas *et al.*, 2012).

Two important mechanisms were observed in Beetle (Scarabaeinae) richness of fragmented Amazonian ecosystems. Beetles had a lower diversity in isolated fragments and also in less tree-rich forests (Filgueiras *et al.,* 2011). In agreement with the last results, a 16-year-old restored Brazilian forests had the highest Scarabaeinae richness, associated with habitat heterogeneity recovery, presenting the highest diversity peak in the rainy season (Hernández *et al*., 2014). In Mexico, beetles were more diverse in places were soil parameters were more stable, decreasing with poor soil management of livestock (De Farias *et al.*, 2015). Staphylinidae followed that trend, being more abundant in preserved oak forests than other gradually more disturbed ecosystems (Caballero & León-Cortés, 2012). In rural agricultural environments of Tanzania, the maintenance of a patchy agricultural landscape was recommended to sustain a healthy diversity of grasshoppers (Caelifera) (Kuppler *et al*., 2015). Dipteran (Sciomyzidae) were also important in temporally-flooded meadows, mainly influenced by the depth and length of the flood season. Therefore, in Ireland, changes in climatic conditions would alter the abundance of this group (Maher *et al.*, 2014).

Higher level identification

Invertebrate soil diversity at higher taxonomic levels can be quite diverse in latitudinal gradients (Cancello *et al.*, 2014), or within the same environment when comparing various functional invertebrate groups (Czechowski *et al.*, 2016). Altitudinal gradients also circumscribed species responses to environmental tolerances, beyond which the whole metacommunity changes (Presley *et al.*, 2011). Soil community composition is one of the main factors to assess ecosystem's quality, the main groups used for this matter are: Formicidae, Acari, Araneae, Orthoptera, Lepidoptera, and Coleoptera (Gerlach *et al.,* 2013).

Lepidoptera is a group that has been used to estimate diversity (Gerlach *et al.* 2013), despite that they are also describing management in human modified ecosystems. Lepidopteran in open Greek grasslands were influenced by the frequency of grazing and soil moisture retention (Kati *et al.*, 2012). Salty marshes in Germany also showed reduced species richness with higher sheep densities, showing that moths were more sensitive that plants (grass) when showing grassland deterioration (Rickert *et al.*, 2012). Lepidopterans in Mediterranean forest showed significant differences in their assemblage after two years of fire, as disturbance event (Elia *et al*., 2012). In tropical forests from Ghana, butterflies regenerated their community composition as the forest gained structural diversity within 50 to 60 years, with very low densities in clear-cut areas (Sáfián, Csontos & Winkler, 2011).

Spiders (Araneae) are also affected by human intervention. Agricultural ecosystems had fewer species than natural ecosystems (grasslands, agroecosystems and forests). Even when diversity dropped consistently between forests, and grasslands and agroecosystems; that trend was not clear when comparing only degraded forest types (Prieto-Benítez & Méndez, 2011). The same trend (in agricultural lanscapes) was observed for native Mygalomorphae in Central Europe (Řezáč & Heneberg, 2014). The presence of predatory arthropods (Spiders on it) in the forest was positively correlated with forest complexity in the Atlantic forest. Disturbed ecosystems reflected a lack on this control that increased the number of herbivores in the forest environment (Morante-Filho *et al.*, 2016).

Within Hymenoptera, Formicidae is perhaps the best described family in the tropics. This family responds particularly to different environmental changes. They recover readily from fire disturbances in temperate (Wittkuhn *et al.*, 2011; Beaumont *et al.,* 2012) and tropical environments (Silveira *et al*., 2016). Influencing strongly in ecosystem services due to predation of other decomposers (Dambros *et al*., 2016; Tarli *et al*., 2014). Ants might also respond to salinity gradients (Dudley *et al.,* 2012; Adeney *et al.*, 2016), and certainly respond to heavy metal accumulation (Ribas *et al*., 2012). This ecosystem engineers have been used extensively to recognize ecosystem recovery (Gerlach *et al.,* 2013).

Coleoptera families have a great variety of feeding behaviour and tolerances, for whichthey can beused as diversity and environmental indicators (Gerlach *et al.,* 2013). Dung beetles present a great importance on biomass decomposition (Kaartinen *et al.,* 2013), decreasing in richness with forest fragmentation (Filgueiras *et al.,* 2011) and habitat degeneration (Silveira *et al*., 2016). Coleopterans were represented by fewer species in introduced tropical grasslands, greatly increasing in native Brazilian grasslands (Almeida *et al.*, 2011). Grasslands in Germany showed a weakening in ecological networks of plant and invertebrate communities, related with farm intensity (Almeida *et al*., 2015). In the same country soil invertebrates increased their feeding activity in presence of grasslands with higher grass diversity and legume presence (Birkhofer *et al*., 2011).

In fynbos from South Africa, the arthropod richness declined due to soil compaction in a gradient from natural to agricultural management, however abundance did the opposite with fewer taxonomic units (Magoba *et al.* 2015). At the mesofaunal and microbial scale, litter addition increased abundance but not diversity in agricultural German lands (Scharroba *et al*., 2012).

In the forest, invertebrates are stratified by vertical composition above ground (Ulyshen, 2011), as well as for below ground (Jiménez-Valverde *et al.*, 2015). Snails enhanced litter decomposition in Hawaiian forests when litter decomposition was analyzed separately just for these macrofaunal taxa (Meyer *et al.,* 2011). Managed forest reduced the invertebrate richness in Indonesia, however, when recovery works started, the abundance dropped but diversity increased in the logged sites (Edwards *et al*., 2012), as did the fynbos in South Africa. In Brazil, ranging from a tree scarce (Caatinga) to a tree rich (Cerrado) forest, herbivore-insect diversity increased with the tree gradient, even when species turnover did not show similar species in the compared ecosystems, the herbivore functional group was higher in the Cerrado ecosystem (Leal *et al*., 2016).

The edge effect in forest ecosystems showed faster litter decomposition in forest interior due to moisture availability and macrofauna intervention in UK (Riutta *et al*., 2012). This result was also observed in tropical ecosystems: in this case, dung beetle richness increased in forest interior (Martello *et al*., 2016). However, velvet-antswere more abundant in the edges, decreasing towards the forest interior (Vieira *et al.,* 2015). The integrated soil quality index (IBQS) proposed in France showed that litter-sensitive macrofauna (from various taxa) was assign to the group that tolerated low pH values and Ca tolerance. This group was prone to be related with forested or undisturbed ecosystems (Ruiz *et al*., 2011). Even when, litter decomposition appears to be greatly dependent on macrofauna in the soil, the same might not be the case in the streams, were macroinvertebrates (70% Chironomidae) from degraded forest played a minor role in organic matter decomposition (Rezende *et al*., 2016).

CONCLUSIONS

The evidence of soil invertebrate variations in community composition are driven by changes (natural or anthropical) in the quantity and quality of litter, as well as soil chemical and physical parameters, which are strongly influenced and disturbed by intensive agriculture, and interdependent linkages of ecological networks. In the tropics there is still more to understand about their behavior and ecology, because only 64% of the studies are focused in tropical or subtropical areas.

The vast majority of responses from temperate regions can be also seen in tropical environments, although the degree of explanation in the tropics has still gaps that require much research. One of the main research lines seems to allocate fire regimes. In this regard, Lepidoptera, Scarabaeinae and Formicidae arethe most studied arthropods of the tropics and temperate regions. That must be partly answered by the fact that they have the most abundant network of identification available, which allows a better understanding of their response to this type of stresses. If other invertebrates might provide more detailed explanation, it is a matter yet to be studied.

Higher taxa determination (Order or higher) does not provide enough information to conclude particular soil invertebrate responses. That information would rather be used as a base line to address the questions that could be answered in the future. Family determination (with limitations) can provide general patterns on insect responses to specific environmental perturbances. Family analysis will help us to understand spatial species turnover and start to understand temporal dynamics. Genus determination will provide insights on specific disturbances or biodiversity interests regarding one ecosystem. However, as soon as we close our attention to one species, we might lose the big picture. This big picture is broadly visible as multiple sensitivity, ecological network strength and functional groups variation. There is also important to note that the baseline needs to be consistent with the methodology. Pitfall traps will only be as accurate as the design that is employed, providing only relative abundances or relative richness. However, spatial or volume sampling is much more demanding, therefore the small amount of research gone for this type of sampling.

Species analysis it is still a task to be completed in the Tropics. Taxonomic determination could be enhanced with modern integrative techniques. It is now that we are just starting to understand the driving forces behind huge changes in the planet (ecosystem services), andthose changes will be better assessed with a clearer understanding of the most biodiverse group of animals on earth.

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