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Biodiversity and Mental Health

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1. Introduction

Humans depend on goods and services provided by natural environments for a decent, healthy, and secure life [1]. There is an increasing evidence of the health benefits to the people exposed to natural environments [2]. Physical health improvement by exposure to natural environments has been attributed mainly to the access and motivation of people to engage in physical activities (the so-called "green exercise" [3]), although, some controversies still remain [4]. It is well-known the positive association between physical activity and health by improving the physical fitness of people [5], and some studies have reported the beneficial impact of exercising to mental health as well [6].

Other studies have found the association between improved mental health and natural environment exposure by psychological mechanisms of restoration, rather than through mere physical exertion [7], or by enhancing social cohesion [8]. However, most of the studies investigating the association between natural environment exposure and mental health had focused on urban settings (green areas) of developed countries, where social, demographic, and geographic contexts, may be different from those of less developed economies. There is a lack of studies about the association between exposure to natural environments or green spaces and mental health in medium to low-income countries. A report of a cross-national prevalence of major depressive episodes, showed a significant higher lifetime prevalence in high-income countries than medium to low-income countries [9]. However, no significant difference in 12-month prevalence of major depressive episode was found.

The chapter begins with definitions about biodiversity and provides some arguments of concern for its current status. Then, from a theoretical and empirical perspective, it is explained the general relationship of biodiversity with human health, focusing on the association with mental health. A special part of the chapter will be the explanation of the underlying theories that give support to the plausible association between biodiversity and mental health. The particular mental health problem being analysed and explained is

depression. Along the chapter, all relevant information for the association of biodiversity with depression will be referred as to what is found or being done in Mexico. The chapter will end with a conclusion about the need for the conservation of the different forms of biodiversity, not only for aesthetic purposes but for the positive impact on human health, despite the gaps in attributing causal effects.

2. Biodiversity

The association between physical environment and health has been known for a long time. In fact, the health and disease process is the result of a permanent interaction of human beings with the environment where they live [10]. The living and physical components of the environment, and the relationships that take place among them, define a particular ecosystem which, when it is disturbed, may produce direct and indirect alterations to the entire set of integrating elements [11]. An ecosystem then, is a complex dynamic group of various living organisms acting as a whole functioning unity [12]. The diverse group of ecosystems, the species living within those ecosystems and the genetic variations within each population, in addition to the process involving their functioning, constitutes what is called biodiversity [13].

Biological diversity or biodiversity refers to the sum of the total biotic variability present in any ecosystem; therefore, it may be estimated in different ways. Although the most common measure is by counting the number of species identified within a time and space frame (known as species richness), there are also other forms of biodiversity measurements. The multidimensional aspect of the concept allows the quantification of biodiversity using three non-exclusive criteria: a) species richness (numeric values of abundance), b) the evenness of their spatial distribution (using biodiversity index), or c) the phenotypic differentiation and genetic variability of the living organisms (at different taxonomic levels) [14]. Approximately, 1.75 millions of species have been identified in the planet, but it is estimated that the real number could be 10 times higher [15]. Ecosystems provide the supporting vital systems for any form of life on Earth, including humans. Not only provide resources for nourishing and fuel, but also they permit the air and water purification, clear and retain toxic substances, degrade waste and recycle nutrients, allow natural and crop pollination, improve soil fertility, buffer out climate change effects, among many other functions and services [1].

With more than 81,000 identified species, and a vast heterogeneity of terrestrial and aquatic ecosystems, Mexico is placed fourth world-wide in biodiversity records. Closed to 10% of the Planet biodiversity lives in Mexican territory, ranking first in reptile diversity and second in mammals, sharing with Brazil the first place in number of ecosystems [16]. In an attempt to estimate the number of species of different taxa (e.g. plants, angiosperms, amphibians, reptiles, birds, mammals, etc.) R Mittermeier created a list of the 17 countries in the world with the greatest diversity, which represents less than 10% of the Planet's surface but host seven out of ten recognised species (Table 1).

CONTINENT	COUNTRIES
Africa	Congo, Madagascar, South Africa
Asia	China, India, Indonesia, Malaysia, Philippines
Australia	Australia, Papua New Guinea
America	USA, Mexico, Brazil, Colombia, Peru, Venezuela, Ecuador

Table 1. Megadiversity countries and the Continents where they are located[17].

Biodiversity, as an important feature of ecosystems, may threaten the continuity of any form of life within when it is affected or diminished. It is estimated that 27,000 species of living organisms are lost annually (about one specie every 20 minutes), which is high above the expected rate of 3 species per year [18]. The global environmental impact due to biodiversity loss has been extensively addressed, but only recently, the focus has been centred on the health consequences of biodiversity loss.

2.1. Biodiversity and health

Human health relies in many ways on biodiversity conservation [19]. When biodiversity is affected, the entire ecosystem destabilizes reducing its resilience capacity, altering the abundance and distribution of living organisms and modifying the interactive relationships among them and with the physical environment as well. In addition, the productivity of the ecosystem is also affected, reducing the benefits that products and services may provide to humans, such as drug biosynthesis from plants and animals [20]. When natural areas are deforested for agricultural use purpose or for new urban settlements, human population becomes exposed to many vectors and species carrying communicable diseases, while limiting the population of natural predators that could exert control over the dispersion of pathogen populations [21].

The main relationship between biodiversity and human health is food provision. However, biodiversity also has direct influence on human health through other pathways not linked to food production [22]. This type of benefits has been observed in urban green spaces, where people reported more psychological benefits and better recovery capacity of mental fatigue as they were exposed to green areas with greater plant diversity [23]. The study conducted in Sheffield, UK, estimated biodiversity as species richness measured by the Gotelli-Colwell index of species density for plants. Total plant richness was the logarithmic-transformed sum estimates for woody and herbaceous plants. Butterflies and bird species were also monitored within the green space, covering a surface of 13 km². Psychological well-being was measured by the administration of a questionnaire to 312 peasants about green space usage for cognitive restoration, positive emotional bonds and sense of identity. The study found that exist a direct positive association between psychological well-being and the extension of the green space, but the association was even stronger as biodiversity increased in the green space, independently from their area sizes.

The potential benefits of biodiversity to physical and mental health have been associated mainly with direct contact of people exposed to natural environments and to the presence of

urban green spaces [24]. Figure 1 exhibits the places where studies have been reported world-wide about the association between mental health and green spaces. On the other hand, the urbanisation sprawl experienced by most of the countries world-wide prevent people from open and permanent contact to natural environments. This isolation could be related to an increased number of diseases associated with urban pollution, sedentary lifestyle, and the automobile traffic overflow [25]. Therefore, all the economic and technological advantages of living in urban settings, become trades-off that jeopardise human health by modifying the environmental conditions where people live and socialize. In reference [26], it is postulated that real progress in public health will only be possible from a more humane and ecological perspective. This approach should be rooted as two fundamental dimensions of public health, that is, capable of reducing social and health inequalities and at the same time promoting health-sustaining environments. In a classical clinical study [27], it was found that surgical patients recovered faster and required less use of pain-relief medication when they could see trees outside from their room windows, as compared to a control group that only could see the walls of neighbour buildings through the windows in the hospital rooms.
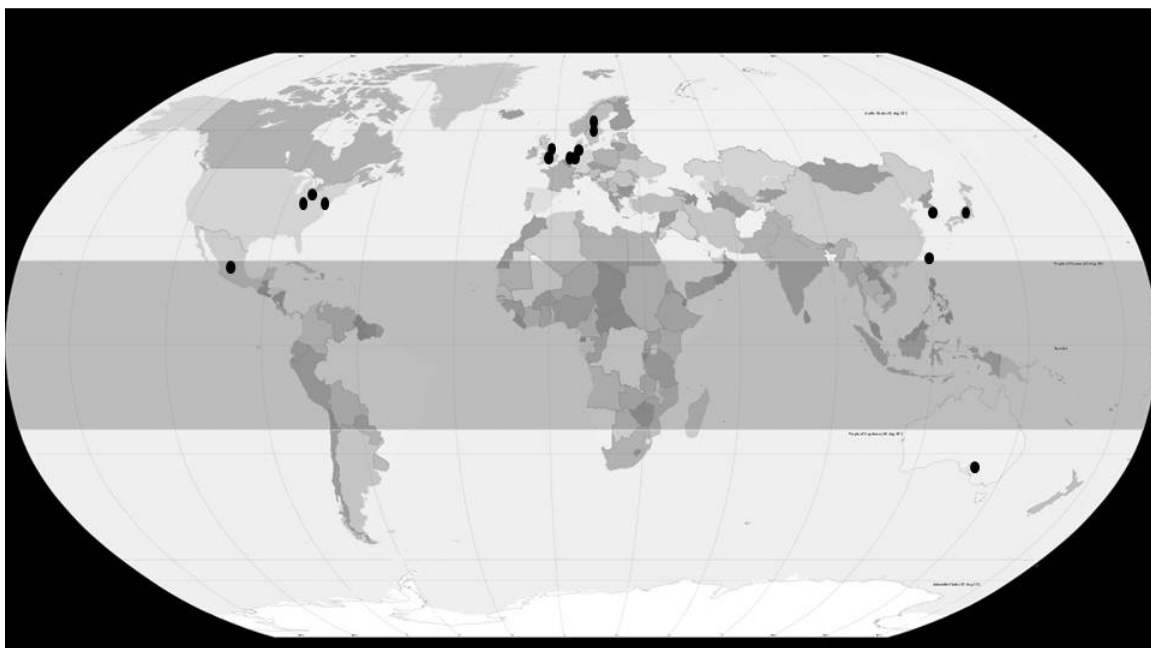

Figure 1. World mapping of the distribution of places were studies about the association of natural environments and green spaces with mental health have been conducted (according to references [2,30,82]).

In another study conducted in the Netherlands [28], it was found that people living in greener areas reported having less illness symptoms, and in general had better self-perception of their health status, including mental health. In such study, the separated effect of urban green spaces, agriculture space and natural environments were analysed, finding the strongest associations of the overall health status improvement with agricultural space living. According to the authors, this feature may reflect a Dutch condition not necessarily shared by other countries, where the green surface in agricultural areas is proportionally

greater than in the other two settings. The results of this exploratory study suggested that the adults exposed to more green space (e.g. housekeepers and the elderly) report fewer symptoms, especially as the educational level increases. Recently, the same research team analysed the Dutch National Survey in General Practice to verify if the positive association found between green space exposure and good health status persisted after medical diagnoses [29]. The results indicated that not only the prevalence of 15 different group of diseases medically diagnosed were lower in residential areas with more green space (measured as the percentage of green space distributed around 1 km from the individuals' place of residence), but such an association was stronger for depression and anxiety.

For some authors, the studies linking the association of green spaces and biodiversity exposure with physical and mental health are still inconclusive, especially in urban settings [30]. However, other voices are claiming more conservation efforts, whether to enhance public health or improve aesthetics, despite any conflicting evidence [31].

3. Environmental and health components

According to reference [32], there are 5 characteristics of an area or place that influence individuals' health:

a. Physical features of the environment shared by all residents in a locality;
b. Availability of healthy environments at home, work, school and play;
c. Services provided (public or private) to support people in their daily lives;
d. Socio-cultural features of a neighbourhood; and
e. Reputation of an area.

The first three have to do with the physical infrastructure of the place, whereas the last two are more related with the collective functioning. These categories are not mutually-exclusive and could interact, which in turn will produce different health effects on people according to their particular biological, psychosocial and economic condition. From this perspective, the study of the health effects related to living in a particular place, need to switch the traditional epidemiological paradigm that blames the individual's behaviour as the cause (or causes) of many communicable and environmental diseases. The complexity of the contexts where the health-disease processes take place, turn the conduction of etiologic studies into searching efforts at multiple time-space levels, in order to avoid the constrictions imposed by the traditional epidemiology of proximal risk factors [33]. For example, it is a myth to think that population health is better in rural environments than in urban settings only because we assume rural people is less exposed to risk factors. Studies have demonstrated that despite the health benefits of contact with natural environments, the unfavourable socioeconomic conditions of many rural people could be as an adverse as to practically wipe out any potential benefit of natural exposure [34]. It is therefore important the inclusion of the context approach where specific risk factors take place in studying population health. Those factors that modify certain health condition in a population, act differently according to the level of organization and analysis [35].

The construction and functioning of the physical and social environment of a particular area may help ameliorate or affect the health of its residents both directly and indirectly. The presence of air pollution is an example of direct effect, when airborne pollutants affect the respiratory health of individuals; whereas food provision in good quality and quantity is an example of indirect effect, when malnutrition make individuals more susceptible to any form of infectious diseases. However, individuals not always can decide the best place for their health (with better environmental quality for instance), and often the selection is indirectly determined by social and economic pre-conditions of the individual related to his or her cultural and historic background [36].

The study of the role the physical environment plays in influencing human health is a key issue in public health. According to WHO reports, environmental factors are responsible for about 24% of the total global burden of diseases [37]. In Mexico, the National Health Program 2007-2012 indicates that about 35% of the total burden of diseases is attributable to environmental factors [38]. The increased rate of species extinction along with the degradation of more than 50% of the ecosystem services world-wide jeopardises life quality and the survival of humankind [1].

3.1. Mental health and biodiversity

Although the study of the effects of contact of nature on mental health is recent, the empiric evidence exists some time ago. Authors like Erik Erikson, Harold Searle, and Paul Shepard have explained about the destruction and exploitation of nature by the so-called Western Civilization along the settlement and development of new societies, which in turn made humans more vulnerable and dependent of the emerging conditions [39]. On the other hand, there are studies focusing on the mental health effects of contact with nature in vulnerable populations [40]. In a study conducted on 112 young adults [7], it was found that the exposed group to a natural environment while doing a hike reported less anger and better humour than the group that did the hike in just urban environment. In another study, patients that were exposed to fruit smell and natural scents, reported lower prevalence of depressive episodes [41]. Animal contact has also be an alternative support method for treating psychological disorders. In reference [42], found that patients with moderate depression interacting with dolphins reported lower depression prevalence after two weeks of treatment as compared to the control group.

There are three fundamental theories (developed in the 80's last century), which try to explain the positive effect on mental health of being in contact with nature:

1. **Biophilia**.- Represents an evolution-based theory defined as the innate emotional affinity of human beings to other living organisms and nature. This feature is rooted in the hereditary aspect of human essence [43]. It is hypothesized that this behaviour is determined by a programed genetic sequence along the course of human evolution which enables a positive response to natural environments in accordance with its own survival. This theory holds that even today human beings are attracted by these natural

environments as they are perceived with a sense of "belonging" (identity) and feel they act in a more efficient manner. Reference [44] considers this nature affinity to be bound deep inside human conscience, which emerges in a similar form as other psychic experiences such as myths, poetry and religion, with a vast and complex semiotic as well. This represents the fundamentals of the moral attitude of respect to any form of life and the value of biodiversity. Based on this perspective, a new concept was developed about the affinity towards diversity (ATD), defined as the individual predisposition to appreciate the variant dynamic interaction of human and nature in the everyday situations [45]. ATD has empirically explained that future-oriented individuals and with more socializing behaviours like altruism and cooperation, tend to high rate pro-social orientation that translate into pro-environmental behaviours. Interestingly, this attitude goes beyond passive acceptance or tolerance, but includes an emotional component that expresses the preference for nature, a sense of guilt for natural resource deterioration and discomfort for actions taken by individuals or companies affecting the environment [46].

2. **Attention-Restoration**.- This theory is based on the works of US psychologist W James at the end of the 19th century. According to this theory, in all individuals there are two areas of mental attention, a) direct attention, which is voluntary an intentional, i.e., one concentrates on aspects regarded as important for oneself. Other less important issues are classified as distractions and have to be blocked by the mind, which in turn produces mental fatigue (direct attention fatigue, or DAF); b) indirect attention (called fascination) which is involuntary and automatic, keeping concentration with low or no effort at all. This allows the brain to recover (or restore), before going back to direct attention [47]. Attention-restoration process takes place in the right side of the frontal cortex of the brain, which from an evolutionary standpoint, being alert and focused was necessary for survival. Natural environments provide the best conditions for restoration, as it allows staying away from daily routine, provide opportunity for fascination and pleasure, a sense of openness that invites the individual to explore, and the compatibility of the natural offering to one's own expectations. Moreover, just by observing a natural landscape may help restore the brain before moving to any direct attention [48].

3. **Psycho-physiologic stress recovery**.- This theory is based on the empiric results observed in the positive responses given by individuals exposed to natural environments [49]. According to this theory, the evolution-based ability of humans to recover from a dangerous situation was a natural selection factor that increased the probability for survival. Under stressful conditions, an individual react following a physiologic mechanism pattern known as the "fight or flight response" [50]. This reaction involves catecholamine secretion (including epinephrine) into the bloodstream, which causes muscular tension, rise blood pressure, accelerates pulse rate, constrict blood vessels and increase perspiration. Thus, an individual is prepared to respond adequately when facing a fatal situation, but can restore back to its original levels once the danger has disappeared or being controlled. Some studies have found that contact with nature causes people to lower their stress level, even at a short time after the

exposure has begun. The theory considers such a response due to a limbic-associated inherently reaction of the brain (a part even more ancient than the cortex), which enabled fit individuals to have greater chances of survival during the course of human evolution [51]. In a similar way as biophilia, genetic plays a crucial role in the development of this theory.

These three theories are still under development incorporating new findings of upcoming studies. Restorative theories (attention-restoration and the stress recovery) try to explain the mechanisms by which the brain may recover after a stressful episode or mental fatigue. The main difference between the two is that the former is a more voluntary mechanism that affects the cognitive process (brain cortex), and it is measured by psychological methods, whereas the latter is more an involuntary reaction involving primitive parts of the brain (limbic system), which is measured physiologically [52].

In summary, when there is a "disconnection" of the natural world where humans live and co-exist, many diverse psychological symptoms arise including anxiety, frustration and depression, which cannot be attributed only to intra-psychological or family driven issues. It has been observed that the contact with such natural world, by means of gardening practices, animal petting, green walk or green exercise, not only relief people from depressive symptoms, but increases human capacity to be healthier, strengthen self-esteem, promotes socializing and makes people happier [53]. Although the positive association between natural contact and mental health has been consistently reported, still remains a challenge determining "how close" this "green contact" should be most appropriate [29].

4. Depression

Depression is a frequent mental disorder that currently affects life quality not only of adults, but of younger people like teenagers and children world-wide [54]. It is characterized by an overall depressed mood, with a loss of interest and/or the inability to feel anymore pleasure for things or situations that formerly produced it, loss of self-confidence and a sense of uselessness [55].

Depression diagnostics is based mostly on self-reported symptoms of patients and on clinical observations, taking as standard criteria the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR[1]) of the American Psychiatric Association (APA). This diagnostic tool was designed to be used with populations in different clinical settings, and represents a necessary tool to collect and communicate statistical information for public health with higher precision [56]. DSM-IV-TR provides a rather descriptive nosology than etiological approach, because it relies more on severity patterns and symptoms duration than in the inferences about the causes of the patient's disorder. DSM-IV-TR uses a multi-axial classification for a complete and systematic assessment of the different mental disorders and medical illnesses, psychosocial and environmental problems and the level of activity. Depression belongs to Axis I clinical disorders as mood disorder, which in turn are classified in depressive disorder (unipolar depression), bipolar depression and two other

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[1] New version (DSM-V) is expected to be ready by mid-2013 according to APA.

disorder based on etiologic causes (mood disorder caused by other diseases and mood disorder caused by drug use). All depressive disorders (e.g. major depressive disorder, dysthymia, and unspecified depressive disorder) can be distinguished from bipolar disorders because there is no history of previous maniac, mixed or hypo-maniac episodes. In general, unipolar depressive disorders are more prevalent than bipolar cases [57].

4.1. Risk factors

In most patients, depressive episodes occur due to a combination of genetic, biochemical and psychosocial factors. According to [58], factors associated with depression and anxiety in the elderly may be classified in those of biological, psychological and social origin. Among those of biological origin are concurrent chronic diseases, especially cardiovascular (high and low blood pressure), cerebrovascular and psychiatric; atherosclerosis, sleeping disorders, low activity level, obesity, hearing or vision impairment, alcohol consumption, tobacco and drug use, and in general with a poor health condition. Among the risk factors of psychological origin are personal traits such as neuroticism and the history of psychiatric disorders. Finally, social risk factors identified for old individuals are low level of socialization, small and scarce social networking, living alone (no partner or spouse), problems with partner or spouse, partner or spouse on depression, low social support, parental overprotection during infancy, stressful life events in infancy, constant victim of violence, aging, among others. In [59] were identified certain consistent risk factors that suggest at least in part, they are probably causally related to the development of a major depressive disorder, and are being female, having had stressful life events, adverse experiences during childhood (e.g. physical violence, parental absence, dysfunctional family, etc.) and certain personality traits. However, the list does not include genetic vulnerability that predisposes individuals to major depressive episodes, nor the severity of such symptoms in the wide variety of depression forms.

4.2. Epidemiology

Point prevalence of depression world-wide is 1.9% in men and 3.2% in women, while for a 1-year period is 5.8% and 9.5% respectively [60]. In USA, life-time major depression prevalence is estimated to be 10.4% in non-Hispanic whites and 8.0% in Mexican-Americans, but when depression is rather moderate and chronic (i.e. dysthymia), the order reversed probably due to the low socio-economic and education levels [61]. According to the Mexican National Assessment Performance Survey (ENED), major depression in Mexico has a global prevalence of 4.5%, having women more than double of men's prevalence (5.8% vs. 2.5%). It was observed that depression prevalence increased with age but decreased as school level of individuals raised [62]. It is noteworthy that ENED reported that major depression prevalence among women is the same in rural and urban settings, whereas in men, prevalence was higher in rural environments than in urban locations. In addition, no defined pattern could be observed in the distribution of major depression among the 32 Mexican states for men and women.

4.3. Seasonal Affective Disorder (SAD)

There is growing evidence that certain mental health problems develop only during autumn and winter season, remitting on warmer and sunny seasons [63]. In USA, between 4% and 6% of adults experience SAD, while 10% to 20% develop mild forms of the disease at the end of the fall season and beginning of winter [64]. Possible causes have been linked to ocular problems to process daylight and to a deficient melatonin secretion in patients that alters their sleep-wake circadian rhythms [65]. Other studies have shown that SAD is probably also associated with problems in serotonergic transmission, since patients under white light exposure treatment responded favourably [66]. Therefore, SAD could be a morbid condition affecting countries with longer winter seasons, even though the association not necessarily is entirely latitude-dependent, and other risk factors such as genetic susceptibility and socio-cultural context could also be playing important roles [67]. Recently, it has been argued the need to consider SAD as a well-defined psychology disorder, since DSM-IV-TR is still classifying it as a cyclic effect modifier in patients with mood disorders [68].

5. Problem statement

World Health Organisation establishes that it is not possible to improve health without including mental health, because it is a fundamental aspect for life quality [69]. If no action is taken, depression is estimated to be second in disability adjusted life years (DALYs) by 2020 world-wide, and will rank first in developed countries [70]. Recent calls for prevention action have set depression as a global priority, considering not only the burden of the disease in terms of treatment cost, but on the loss of productivity as well [71]. The implementation of preventive measures to treat any disease is always desirable over the usually costlier and bothersome curative methods [52]. However, it remains unknown what is the most effective strategy to reduce depression prevalence; it is still necessary to bear in mind that prevention is one of the first goals of public health. Although there is an increasing research production aiming at studying the association between biodiversity and mental health, it is unknown the existence of specific studies in low-to-medium income countries that focus on contextual determinants associated with depression.

Depression is one of the most important diseases among Mexican adults, being the second mental disorder reported in urban settings, just after alcohol consumption [72]. Some conditions of vulnerability were identified associated with major depressive episodes, such as aging, being women, having low educational levels, and living in socioeconomically deprived areas. There is no doubt about the association between the stressful urban way-of-life and depression in adulthood. However, in the Mexican National Assessment Performance Survey (ENED-2003), data showed the same prevalence of depression symptoms between urban and rural women, but was even higher in rural men than in city men dwellers. In addition, depressive symptoms prevalence distribution per political

division (State) was different between men and women, with no clear geographical pattern [62]. For men, the States with the highest prevalence were Jalisco (5%), Veracruz (4.6%) and Tabasco (4.5%), whereas the last two in the list were Nuevo León (less than 1%) and Nayarit (less than 1%). In women, Jalisco was also high with (8.2%) just after Hidalgo (9.9%) and before Estado de México (8.1%). The Mexican States with the lowest prevalence of depressive symptoms in women were Campeche (2.9%) and Sonora (2.8%). In Table 2 is possible to see the results of the total prevalence of affective disorders (including depression) for each of 6 geographic zones identified in Mexico [73]. Of note are the lowest prevalence rates registered in the South-eastern states, where biodiversity and economic deprivation are high [74, 75]

Affective Disorder	Northwest	North	Central West	Central East	Southeast	Metropolitan Areas	TOTAL
Anytime	8.4 [1.6]	9.0 (1.1)	10.2 (1.5)	10.6 (1.6)	5.7 (1.5)	10.4 (0.9)	9.1 (0.6)
Last year	4.5 (0.9)	4.6 (0.7)	5.6 (1.0)	4.9 (0.6)	2.2 (0.6)	5.3 (0.9)	4.5 (0.3)
Last month	2.4 (0.4)	1.9 (0.3)	2.5 (0.7)	2.1 (0.6)	0.9 (0.3)	2.2 (0.5)	1.9 (0.2)

Table 2. Prevalence of affective disorders by geographic zone in Mexico according to reference [73]. Standard error values are between brackets.

It is important to remark that not only humans are under stressful conditions. Planet Earth as a whole is jeopardised on its basic functions due to alterations in its structure, composition and resilience. The UN Convention on Biological Diversity (UNCBD) estimates biodiversity loss currently is close to one thousand times the natural extinction rate, and it is possible to rise in the upcoming years: around 34,000 plant species and 5,200 animal species are in danger of extinction [76]. The Millennium Development Goals entails conservation efforts for biodiversity under its seventh proposal "Environmental Sustainability" [77]. In addition, the conservation and promotion of health-sustaining environments is one of the new challenges of public health intervention [26]. In cases like Mexico, a mega-diversity country, the efforts are more than justified since the benefits to improve population's mental health have been demonstrated.

6. Research evidence

In a recent systematic review, the results of 25 studies analysing the association between green spaces and overall health and well-being were compared, finding positive consistency between exposure and some mental health-related emotions [2]. In Table 3 can be observed the results of the study where the effects of the before-and-after exposure to natural environments were compared among individuals. Consistency of results was lower when the variables were physiologically measured. These meta-analytical findings

provide high internal validity to the plausible association; however, the lack of context variability (whether physical or social environments), could limit the external validity of the results. This is what reference [78] calls *psychologistic fallacy*, where individual-level studies lack the inclusion of contextual variables that may explain the apparent variability observed.

OUTCOME	EFFECT SIZE	95% CI	No. STUDIES	RESULTS
Attention	0.23	(-0.30, 0.76)	3	No effect
Energy	0.76	(0.33, 1.22)	5	Improved
Anxiety	0.52	(0.25, 0.79)	6	Improved
Tranquillity	0.07	(-0.42, 0.55)	7	No effect
Anger	0.35	(0.07, 0.64)	6	Improved
Fatigue	0.76	(0.41, 1.11)	4	Improved
Sadness	0.66	(0.66, 1.16)	3	Improved
Diastolic BP	0.32	(-0.18, 0.82)	3	No effect
Cortisol	0.57	(-0.43, 1.57)	4	No effect

Table 3. Results of the effect size (*Hedges g*) of the studies that measured health status before and after exposure to natural environments. OUTCOME = Psychologic/Physiologic variable measured. EFFECT SIZE = Group measure (Hedges g). 95% CI = 95% Confidence Interval. RESULTS = Interpretation of statistical results

Most research on the aetiology of depression and its treatment, have focused on identifying individual risk factors [79]. From a public health perspective though, it is still desirable to keep efforts on preventing the occurrence of depression rather than only in improving diagnostics and treatment efficiency [52]. In a review including more than 30 randomised control trials, it was demonstrated that different preventive interventions can reduce the incidence of major depressive episodes by as much as 50% [80]

In another systematic review of 28 studies [81], the association between physical and social characteristics of the neighbourhoods and depression in adults was analysed. The study found evidence of the negative effects of economic deprivation and the protective effect as this economic condition improved. On the other hand, the association between physical environment and depression was less evident, probably due to the few studies that incorporated the physical dimension of the neighbourhoods. Therefore, socioeconomic characteristics of higher levels of aggregation (such as individuals' place of residence), have a demonstrated effect in the mental health and well-being of the exposed population, acting independently or as effect modifiers of individual risk factor (Figure 2), but this association is less clear with the physical attributes of the environment.

In an ecological study of the association of depressive symptoms prevalence and some biodiversity indicators (measured as non-aquatic animal and plant species richness and green areas) in Mexico, it was observed that at an aggregate-level of analysis, biodiversity was positive related to depressive symptoms [82]. In other words, the study suggests that as biodiversity increases (measures as all non-aquatic species richness) in a state,

depressive symptoms increase as well. For this study, data analysed were obtained from different sources. The outcome set of depressive symptoms was taken from the Mexican National Health and Nutrition Survey, ENSANUT-2006 [83]. ENSANUT-2006 was a cross-sectional survey with a probabilistic, multistage, stratified and clustered sampling. The survey collected data from October 2005 through May 2006 on health and nutritional status of the Mexican population, health services quality, public health policy and programmes, and health expenditures of Mexican dwellers [84]. The survey's structure allows representative estimations to the national, state and local levels, for urban and rural areas defined according to the population size (rural settings with less than 2,500 inhabitants; urban settings from 2,500 up to 99,999 inhabitants; metropolitan areas from 100,000). Depressive symptoms in adults were defined as those of men and women aged 20 to 65 years old, who declared having at least 5 of the following symptoms during most of the day for a period of at least one-week (DSM-IV definition of major depressive episode establishes such symptoms over a period of two weeks, therefore, we kept the focus rather on depressive symptoms only): 1) depressed mood; 2) markedly diminished interest or pleasure in almost all activities; 3) significant changes in appetite or weight; 4) insomnia (or hypersomnia in some cases); 5) psychomotor agitation or retardation; 6) fatigue; 7) feelings of worthlessness; and 8) diminished ability to think, concentrate or make decisions [56].
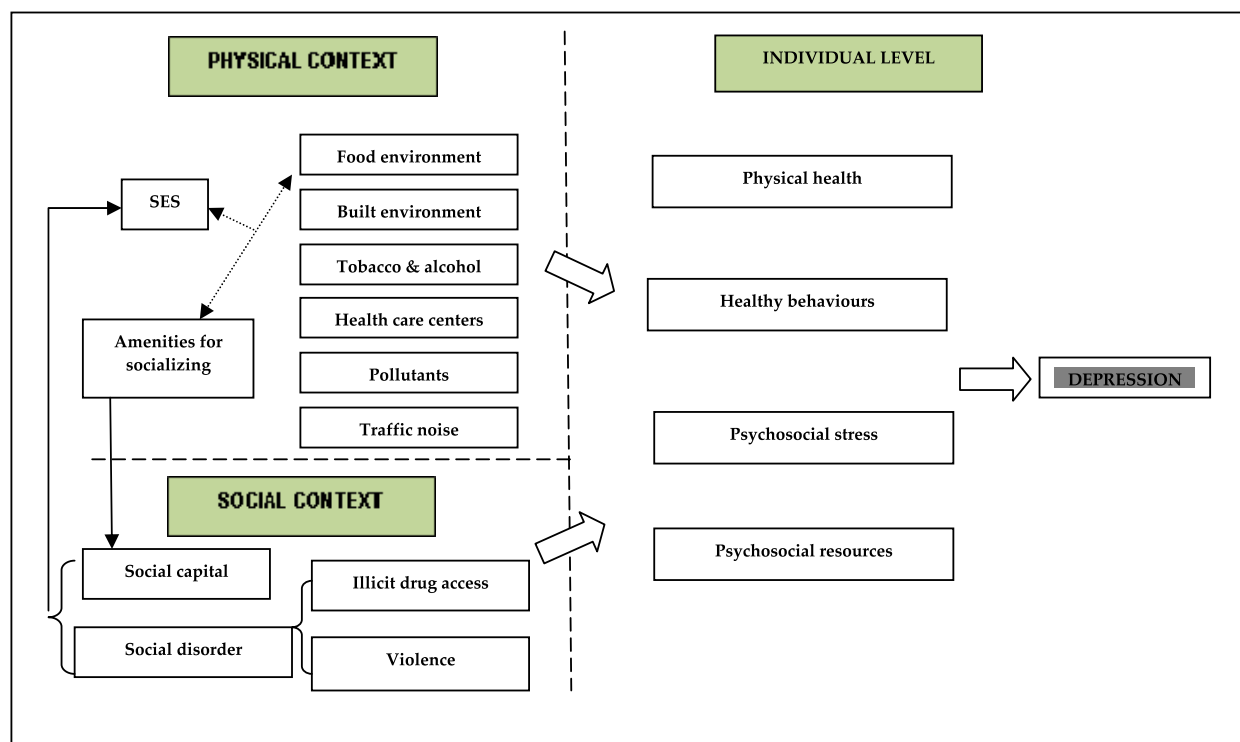

Figure 2. Neighbourhood contextual and individual risk factor model for depression in adult (modified from [81]).

The conditions were built from ENSANUT 2006 aggregating up to a state level the proportion of women, average age, and proportion of self-described as native-indigenous people. From the Mexican Compendium of Environmental Statistics 2008 [85], information was extracted per state for several biodiversity indicators such as animal (non-aquatic) and plant species richness, proportion of reforested land, proportion of natural protected areas, agricultural area and livestock grasslands. We based our ecological measure of biodiversity on the guidelines suggested by the Organisation for Economic Co-operation and Development for building environmental indicators [86].

Natural protected federal area proportions were determined according to the number of states included within its limits. The territory surface area for each state was used to calculate the proportion of green spaces occupied by re-forested, agriculture area-livestock grassland, and natural protected areas in all Mexican states. Animal and plant species richness were summed to account for the total species richness (non-aquatic biodiversity). In addition, economic disparity values were taken as Gini coefficients from the National Population Council [75], as well as the deprivation index data base. Both are measures of unfavourable socioeconomic conditions at group level, the former as an index of income-distribution inequality (the higher the value, the higher the inequality), whereas the latter measures the level of poverty based mainly on education and living conditions. Drug, tobacco and alcohol use data were obtained per state from the Mexican National Addictions Survey 2008 [87], whereas aggregate insecurity perception of individuals in every state was taken from the Mexican National Survey on Insecurity [88].

These unexpected findings are somehow in agreement with the results of a similar study in which a negative association of biodiversity with life expectancy at birth (LEB) was observed in Mexico [89]. Such eco-epidemiological study used 50 environmental indicators with information about demography, housing, poverty, water, soils, biodiversity, forestry resources, and residues were included in an exploratory factor analysis. Four factors were extracted: Population vulnerability/susceptibility, and biodiversity (FC1), urbanization, industrialization, and environmental sustainability (FC2), ecological resilience (FC3), and free-plague environments (FC4). Using ordinary least-squared regressions, it could be observed that whereas FC2, FC3, and FC4 were positively associated with life expectancy at birth, FC1 (biodiversity component) was negatively associated (Table 4). The results showed a South to North gradient inverse to the tendency with LEB. The author recommended including the physical environment as important macro-determinant when studying Mexican population health.

In another study conducted in USA, all-cause mortality in 47 largest USA cities was found to be higher in those having more green spaces [90]. They conclude that it is important the kind of contact that urban residents may have with their natural environment and the form of the green spaces as well, in order to expect the health benefits to the population, otherwise, the sprawling characteristics of USA cities may distort the positive association.

Variable	Total population			Men			Women		
	β	IC95%		β	IC95%		β	IC95%	
FC1	-0.71	-0.76	-0.64	-0.80	-0.88	-0.72	-0.62	-0.68	-0.56
FC2	0.14	0.07	0.21	0.14	0.06	0.22	0.13	0.07	0.19
FC3	0.07	0.00	0.14	0.09	0.01	0.17	0.06	-0.00	0.12
FC4	0.09	0.02	0.16	0.11	0.03	0.19	0.09	0.03	0.15
Adjusted r^2	0.9376			0.9344			0.9393		

FC1: population vulnerability/susceptibility and biodiversity.
FC2: urbanization, industrialization and environmental sustainability
FC3: ecologic resilience.
FC4: environments free of forest plagues.

Table 4. Impact of environmental factors on life expectancy at birth estimated with multiple linear regression models.

7. Conclusions

CE Winslow stated in 1920 that one of the goals of public health was prevention. Nowadays, the number of goals has increased as the population health becomes an emergent property of complex systems [91], but certainly prevention is still at the first place in the list. The challenge would be to find evidence-based effective preventive interventions [92]. Currently the relationship between biodiversity or green spaces and human health is not clear. The bulk of available evidence relating natural environments (with more biodiversity than built environments) and positive health outcomes is mainly based on data from regions with higher income and more development, which are not representative of heterogeneity of countries with less economic and human development. Studies from Latin American countries, Asia and Africa are urgently required to have a full understanding of the relationship, because there is evidence obtained in studies on other determinants of health suggesting a selection bias when data of countries with different levels of economic and human development are not included [93]. The limited evidence from developing countries, as Mexico, on biodiversity and depressive symptoms [82] and life expectancy at birth [89] is contrary to the findings in developed countries. Possible explanations to this difference include the high correlation between social determinants as income inequality, social capital, and level of democracy.

Despite of this methodological limitation to understand the causal relationships between biodiversity and depression, another plausible explanation can be related with latitudinal differences, because biodiversity decreases in regions distant from the tropics, thus, exposure to natural environments can exaggerate the positive effects. Some studies report an association between latitude and affective disorders [94-97]. An alternate explanation is related with the unit of analysis, because results of individual-level studies not necessarily

are the same as those observed when analysing populations [98]. Favourable effects of biodiversity on health only have been observed in individual-level studies, whereas adverse effects have been reported in population-level studies [90]. These kinds of results are not surprising, and they are consequence of inherent limitations of science. Epidemiological and psychological studies are unable to detect the effects when low variability is present among the individuals or populations included in the studies since these approaches are based on the comparative methods.

In conclusion, we suggest that exposure to biodiversity can be good for health if the individuals are in built environments with adequate social conditions. These characteristics are frequent in Northern-European and North American countries. In contexts with higher biodiversity, the results can be ambiguous depending of the type of urbanisation [99]. As a consequence, more research in these regions is required because characteristics of the physical environment can be directly or indirectly correlated with social determinants. On the other hand, since different results are observed when studies are with individuals or populations, it is needed to include both approaches in multilevel studies. The inclusion of ecological concepts and methods will be useful to improve the quality of further studies on biodiversity and human health.

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