CAN CHOCOLATE BE ADDICTIVE?

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Abstract—Addiction term is often associated with alcohol, drugs, but currently there is also a new type of addiction that is widely debated called the food addiction. There are different types of food in the world each having its own desirable characteristic to be claimed addictive. One such type of food that is popular and explicitly craved is chocolate. This is a review of literature on consolidating the possible causes and reasons to prove whether chocolate can be as addictive as any other addictive drugs. Chocolate’s unique sensory property, its hedonic appeal and the psychoactive agents like methylxanthines, cannabinoid, like fatty acids and biogenic amines that resembles drug like effects are being explored. This review also covers the influence of gender, age groups for chocolate preference. It also validates what kind of chocolate is mostly preferred. It is relevant to say that food items we consume have an impact on our emotions. Therefore, the emotional and behavioral aspects of chocolate eating and stimulation of chocolate cravings are being evaluated and what makes it to elicit drug like effects is being elucidated. The uncontrollable craving of chocolate can land into bingeing disorder or disordered eating is something being speculated and the need to be controlled is stressed. Finally, the question on the existence of chocolate addiction is being answered.

I. INTRODUCTION

What is it that is so special about chocolate? Chocolate is mostly the gifts given on Valentine’s Day, to a kid as a token of appreciation on his finished homework and chocolate is even used to convey their delicate sweet sorry. Why people love it so much? Is it just a “crave” people can’t resist or it is a harmless drug that could be “addictive”?

“Gotta have it is the driving thought of an addict; a drink, a drag, a hit, a line, a pill, another piece of chocolate….This urgent demand overrides all others, undermines reasons, resolve, and will….It doesn’t stop until it is satisfied. And then it starts again” [1]. The first time the term addiction was used to relate to chocolate in the Quartery Journal of Inebriety (QJI) in the year 1890. Since then, the addictive properties of chocolate caught the attention of both scientists and researchers making it a topic worth debating, as chocolate could be seen scientifically analogous to addiction [2].

Chocolate was once seen as a luxury, but now more than a confectionery that is dearly held by a lot. Chocolate never ceases to amaze us, starting from its mood altering properties to creating a seductive sensory experience. Chocolate still makes an interesting subject in this 21st century where researchers are still intrigued to unravel its ubiquitous nature. Before getting to know the unique properties that chocolate hold which puts forth questions that is it similar to any drug or does it exhibits drug like effects leaning down to the final end whether chocolate consumption could turn into an addiction.

II. THE ORIGIN AND ITS EVOLUTION

About 4000 years ago, it was established that the beans of the tree, Theobroma cacao, indigenous to Central America is responsible for the creation of chocolate. It was handled by the people of Mayan followed by Aztec. Back in time, beans obtained from trees of cacao were classified into two prime categories based on its qualities: the high quality beans were mentioned as quauhcacahuatl that were considerably made use as a type of currency, while the tlacacahuat meant the least standard beans that were used in making drinks. This drink was a blend of cacao and water, which was the named by the people of Aztecs as xocalatl. The year 1554 when chocolate made its debut in Europe, which was introduced by the Spanish. The desire for chocolate started escalating manifold. It was competing with coffee and tea and became a drink that everyone consumed almost every day. Around mid 1660s to 1880s chocolate were proclaimed medicinal and it was blended with different spices from pepper to aniseeds and even vanilla to exert its medicinal properties. Chocolate is considered to be both therapeutic and beneficial for health and it is aphrodisiac in nature [3]. Cacao just didn’t remain a drink anymore, it started evolving in many ways.

It was Joseph Fry in the year 1847 who invented the first bar of chocolate combining sugar, beans of cocoa and cocoa butter. In the year 1875, Milk chocolate was created by Swiss Daniel Peter and Henry Nestle. The discovery of dark chocolate in the year 1879 by Rodolphe Lindt by a process called conching (method of obtaining smooth texture of cacao by grinding the mixture with the application of heat). Then came one of most favourite brands Cadbury with its “Kisses” in the year 1905 then Hershey pleased us by inventing “Kisses” in the year 1907 [4].

Chocolate doesn’t stop at being just a confection delicacy. Researchers have said that chocolate changes our mood, creates pleasurable sensations. It bursts out euphoria on every bite of it instigates memories of one’s delicate part of life. Probably that is not the case when you consume other foods. Chocolate has grown into a global fascination. It is true that chocolate is said to be the “gift of gods” [3].

“CHOCOHOLICS”

A neologism: “chocoholics” was formed by blending chocolate and alcoholic [5]. Is this so called term “chocoholics” was coined for people who are head over heels in love with chocolate? Or can we say they are “chocolate-addicts” who can’t resist? An experiment conducted with 61 participants was a given a questionnaire based on their food craving, the food they frequently think about and the foods they often snacked on every day, continued by Ecological Momentary Assessment (EMA) for a week. It was concluded that about 86 percent of the participants declared their affinity towards foods consisting of chocolate [6]. Why people think
they are addicted to chocolate? Though we all know chocolate aren’t even a staple part of the diet, we do recognize that “should be eaten with restraint,” and “I would like to eat more but I can’t” part later kicks in. Anyway, these thoughts can’t sustain one from consuming chocolate. These create craving feelings, later when one fails to address one’s indulgence in chocolate one inevitably claims it as an addiction. The Chocolate comes under the most desired foods, due to its palatability and it is claimed to be “addictive” because of its specific oral sensory properties that induces hedonism, followed by the presence of psychoactive agents resulting in pharmacological effects and other biological agents [16] packed together that makes chocolate not just desirable but initiates a conception of behavioural aspects and emotional side of eating [7].

III. HEDONISM, HYPER-PALATIBILITY AND CRAVING

Chocolate is considered to be a hedonic substance (evoking pleasurable sensory experience) as fat and sugar in it plays a major role in inducing craving like feelings. Those feelings aggravate one into disordered eating or binge eating disorder. Fat and sugar elicits a greater sensory experience by enhancing its palatability making chocolate a hyper-palatable food. Researchers have found foods rich in sugar and fat significantly called as hyper-palatable released drug-like effects [2,8,9]. Probably, the very first addictive nature of chocolate is considered to be its hedonic appeal. Researchers conducted experiment with rodents to check the addictive nature of sugar and fat. The rodent model of sugar and fat bingeing supported the idea of high sugar and high fat as the rodent self imposed bingeing even in the absence of hunger, producing a sense of addictive like effects [2,8-11] and combination of both high fat and high sugar food had stronger addictive like effects [10]. The reasons for these effects are due to the brain’s neurochemical effects. The neurochemical effects (the mesolimbic dopamine system) generated were alike to drugs of abuse followed by withdrawal symptoms. The mesolimbic dopamine system, the quick absorption rate is why we feel it pleasurable [2,8-11] when consuming chocolate like hyper-palatable foods. The modes of addiction involves bingeing and not forgetting the endless craving, entire dependence and finally revealing withdrawal symptoms [11]. The same rodent model exhibited that sugar showed cue of opioid withdrawal symptoms. We can say that chocolate having a great appeal of hedonism and hyper-palatability showed properties similar to addictive drugs. The preliminary addiction to chocolate might reside in its unique sensory properties that is inducing the potential craving but bingeing of the same is due to the brain’s neuropharmacological activities.

TABLE 1. Similarities Between Hyperpalatable Foods and Addictive Drugs

1. Activate dopamine and opioid neural circuitry
2. Trigger artificially elevated levels of reward
3. Absorbed rapidly into the blood stream
4. Alter neurobiological systems
5. Cause compensatory mechanisms that result in tolerance
6. Combined with additives to enhance rewarding properties
7. Elicit cue-triggered cravings
8. Consumed in spite of negative consequences
9. Consumed in spite of a desire to cut down
10. Impact disadvantaged groups to a disproportionate degree
11. Cause high public health costs
12. Exposure in utero can result in long-term alterations

Adapted from Gearhardt et al [8]

IV. CHOCOLATE AND NEUROTRANSMITTERS:

There are multiple reasons why one consumes chocolate. It could be the essentiality in increasing one’s magnesium level or it could be the pleasure it evokes when consumed. A sense of euphoria it provides, Is that the reason when we say just one bite of chocolate we doesn’t stop at it? The neurotransmitters that activate this feeling are dopamine, serotonin and endorphins [14]. It is admitted that mesolimbic dopamine system are activated to elicit motivation and in mediating reward. Overflow of this neurotransmitter can occur when palatable, foods like chocolate reward is encountered [12]. The dopamine creates its control mechanism by creating a memory [13,14] of the primary reward. Then it stimulates the “wanting” desire [12]. Serotonin is said to generate cravings and other mood alterations [14]. As chocolate is a carbohydrate rich food. When carbohydrate is ingested into the system, the production of insulin happens along with anabolic effects which leads to synthesis of amino acid except for tryptophan. Due to this there is a boost of tryptophan over other amino acids. There occurs a competition for crossing the blood-brain barrier, resulting more of tryptophan entering the brain, leading to the elevation in the production of serotonin. But this is the case when the chocolate contains less than 6% protein [15]. But generally chocolate’s protein content is more than 6% [16] so, this is the not the possible cause for serotonin synthesis [14,16] but it was also reported that the intake of carbohydrates did change mood without the synthesis of the serotonin providing there could be some other mechanism involved too. Continuing with another neurotransmitter endorphins, the opioid system releases an opioid called Π-endorphins when palatable foods are administered intensifying the pleasure of eating. Furthermore, it was mentioned that the strength of craving is associatively higher in opioid than serotnergic system. It has been put forth that the endogenous opioid peptide (EOP) system improves the dopamine system of modifying food reward value process in the mesolimbic pathway [14]. Therefore, these three neurotransmitters play the role in managing what we eat.

V. PSYCHOACTIVE AGENTS

The ultimate desire elevating the mood changes for chocolate can be said due to the orosensory properties but there is more to it. It is been widely debated that the psychoactive agents present in the chocolate like methylxanthines, biogenic amides, cannabinoids like fatty acids might be the reason behind the “addiction”; “craving” of chocolate. It is believed that these psychoactive active agents are responsible in creating sensations that motivates in eating chocolate more and still is widely its truth is being studied.
VI. METHYLXANTHINES

Methylxanthine is one of a psychoactive agent in chocolate. The major methylxanthine present in chocolate is caffeine (1,3,7-trimethylxanthine) and theobromine (3,7-dimethylxanthine). The blocking of adenosine receptors by methylxanthines causes various physiological effects [17,19]. MAFF. Survey of Caffeine and Other Methylxanthines in Energy Drinks and Other Caffeine-containing Products measured the samples of chocolate containing amount of presence of both caffeine and theobromine. It was identified that 4 samples of a typical 50g size of milk chocolate contained 8-4mg of caffeine and 95mg of theobromine and 2 samples of 50g sized dark chocolate contained 27mg of caffeine and 378mg of theobromine. This proves caffeine is present in smaller amounts, but theobromine is present in abundance [17,19]. In a study comparing the subjective effects of theobromine and caffeine, Mumford et al. [20] recognized that the caffeine had an effect on mood, behaviour, and other physiological properties in low quantity. Whereas theobromine though present in abundance it didn’t show any quick effect. Theobromine took a long time in displaying those physiological effects and the effects were subjectively minor or its effect on central nervous system was considered almost inert when compared with caffeine [19]. Another study conducted by the Smith et al tried displaying the pharmacological effects of theobromine and caffeine present in cacao. The authors conducted two double-blind, placebo-controlled studies to find the effects of cognition and mood of the amount of cacao powder and methylxanthines found in a 50g of dark chocolate, the participants were given three varieties that were visually similar quantity of high (20mg caffeine + 250mg theobromine), low (8mg caffeine + 100mg theobromine) amount of methylxanthines in milk and dark chocolate and white chocolate which contained no methylxanthines. It was followed by a long duration simple reaction time task, a rapid visual information processing task, and a mood questionnaire, the results illustrated that the presence of methylxanthines was indentified as the major reason for the pharmacological activity like increase in the performance of cognition of chocolate but it didn’t explain the craving desire of chocolate [18,20]. From both the study, we can conclude that the pharmacological effects of chocolate was exhibited when theobromine and caffeine are present in combination. Talking about the addictive property of methylxanthines, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition by the American Psychiatric Association asserted that caffeine was the only methylxanthine qualified the criteria for substance dependence to some extent [21]. Studies which conveyed the addictive effects of methylxanthines other than caffeine had no proof in conferring its identification as substance dependence. Foods that contain high caffeine content does have withdrawal symptoms creating rewarding properties but not much as reinforcing properties [22]. As chocolate’s caffeine content is low which potentially cannot be accounted for the addictive nature. we could call it as an energy booster. Methylxanthines do play a role in the liking chocolate, but we cannot say that authenticate to evoke craving nature [23].

VII. BIOGENIC AMINES 2-PHENYLETHYLAMINE

2-phenylethylamine (PEA) is a biogenic amine that is present in the brain in traceable amounts [24,25]. It is generally present in foods like chocolate, wine and cheese. It was reported that chocolate had the highest presence of PEA of about 3.5-8.02 mg/g [26].

PEA is claimed as the “endogenous amphetamine” [27]. Phenylalanine is one of the precursors of biogenic amines. The decarboxylation of this precursor leads to the synthesis of PEA. Monoamine oxidase type B (MAO-B) is responsible for the metabolism of PEA. The release of neurotransmitters such as dopamine, serotonin, nonadrenaline is caused by PEA [25]. Predictions regarding PEA were widely preached by Liebowitz and Klein [29], who recognised an affective disorder involving atypical depression, intolerance to personal rejection and attention-seeking behaviour, which they termed “hysteroid dysphoria” and this was associated with an abnormal regulation of PEA. It was claimed that the production of PEA is “stimulated by positive life events”, and that “depressed, hysteroid dysphorics often binge on chocolate, which is loaded with phenylethylamine”. PEA has been often linked with romance, love, and sex. For example, PEA was linked to euphoric feelings that was experienced in a sexual activity and in love [30]. “When scientists injected some mice with PEA, they jumped about and squealed with a kind of mouse exuberation and exhilaration animal behaviourists call ‘popcorn behaviour’. When rhesus monkeys are injected with PEA they smack their lips and make pleasure calls, much as they do when they are courting another monkey. Baboons injected with PEA will press a lever in their cage more than 160 times in three hours when pressing that lever will give them PEA-laced food that maintains their high PEA level of euphoria” [19]. After all these experiments, Shulgin and Shulgin [31], induced oral doses of PEA of 200-1600 mg and 25-50 mg of doses intravenously. It was found that the effects that was witnessed on animals could not be reproduced in human beings. This poses to a conclusion that PEA showed no subjective effects on humans. Therefore, this results in the contradiction of what was supported by Liebowitz and Klein. A research illustrated the chronic and acute effects of administration of PEA intravenously and it was found that the striatal 5-hydroxytryptamine level increased, leading to depletion in striatal dopamine when administered acutely and chronic administration resulted in reverse including changes in the behavioural system. While, no difference was examined when PEA was administered orally [27]. Although PEA is present in higher concentration in chocolate, however, it is irrelevant in people who are healthy as biogenic amines are inactivated by metabolism by the enzymes of MAO-B in the mucosa of the small intestine, in the liver, and in the kidney [16,28].

As the research does not substantiate the effects of PEA in chocolate, the oral and intravenous injection are reasonably dissimilar things. The popular convictions about PEA bloomed manifold regarding chocolate as “sex substitute” [32].

VIII. CANNABINOID LIKE FATTY ACIDS

Anandamide (N-acylethanolamines) is a lipid neurotransmitter. Anandamide is also termed as the “internal bliss.” Accountable reasons for the pharmacological effects of a psychoactive component called Δ
9-tetrahydrocannabinol (THC) present in cannabis sativa is caused by anandamide. Studies suggest that anandamide is associated with producing addiction [33]. Di Tomaso et al. [34] found that two unsaturated compound oleoylethanolamine and N-linoleoylethanolamine present in chocolate along with anandamide inhibited anandamide and did not activate the cannabinoid receptor. Further evidences suggested that these compounds were present only in chocolate and cocoa powder and not in white chocolate. Without any evident proof, Di Tomaso et al claimed that the anandamide had the capacity to produce euphoric feeling and high that intended in elevating the sensory properties of chocolate. However, it was mentioned prior that anandamide is the reason for producing pharmacological effects in Δ 9-tetrahydrocannabinol (THC), it was evident that those potential “high” can only occur under a dosage of 1.3mg for a body weight of 70 kg and chocolate contain tiny amount of about 0.05 micro gram/gram. Therefore that result would be achieved only when one consumes a 25kg of chocolate for a weight of about 70kg [35]. A study found that anandamide and another cannabinoid 2-arachidonoyl- glycerol increased when food containing high hedonic appeal was consumed but the same compounds present in chocolate as mentioned former didn’t show such result as it was immediately broken down [36].

IX. MOST PREFERRED CHOCOLATE

As we are familiar with 3 types of chocolate the dark chocolate, white chocolate, milk chocolate and also including the greatest invention recently by the barreau callebaut company the ruby chocolate. Considering this 4 different types of chocolate, the ruby chocolate was considered the least preferable [37] due to his sensory properties but more study needs to be done on that. Regarding the well know and widely consumed rest three, it was proved that milk chocolate was highly preferable as it had the perfect sensory appeal. The sugar to increase the palatability and the fat (cocoa butter) in addition to that presence of the psychoactive agents enhances the mood giving in the pleasurable feel while comparing that to white chocolate where one can argue it has the same sensory properties but it lacks the amount of psychoactive agents that could be seen in milk chocolate and finally dark chocolate having the highest amount of psychoactive agents lacks the hedonic appeal that of milk chocolate has [38]. This confirms that the psychoactive agents are not the entire reason of one’s liking for chocolate, if that is the case then dark chocolate would be the preferred. This inclines to the orosensory properties are the basis for one’s liking towards chocolate. After a few years, there was another study conducted on the psychoactive effects of chocolate and the desirability of chocolate. Participants were asked to choose chocolate with varying cocoa content and followed up with a questionnaire and it was found that the psychoactive effect was constructively linked with its orosensory properties activating the neurotransmitters like dopamine and opioid receptors creating the desirability [39]. To summarise, according to the latter research we can say that the sensory appeal is the major influence for craving like feeling and the presence of psychoactive agents essenuated the desire for eating more.

X. GENDER, AGE GROUPS AND CHOCOLATE

Chocolate craving was not equal in genders. Sex differences played an important role in the interest of consumption of chocolate [40]. According to a survey that was taken in India, it appeared that about 60% of women consume chocolate as they relate chocolate to happiness and 57% of male relate consuming chocolate to satisfaction. The research also mentioned craving for chocolate could be the memories of the past consumption that induces one to eat more [41]. It was found that North American countries craved chocolate deeply and including the gender differences, it was noted that 90% of women craved chocolate in accordance to 60% men and 45% of undergraduate American women to 17% of undergraduate American men. This quite proves the gender do play an interest in chocolate craving [42]. Reports said that women preferred chocolate than men [42-45]. This preference can widely hold for American but this gender difference for craving isn’t definite information on Spanish people [46]. This instigates a question why do women prefer chocolate more? Does that associate anything with the perimenstrual cycle? Here is a summary of mechanisms hypothesized to play a role in the etiology of perimenstrual chocolate craving [47]. Though chocolate craving during perimenstrual cycle could be due to the many factors mentioned below. It could be hormonal [49] and later it was proved that the perimenstrual craving is culture bound. This practically applied to the women of North American countries and also an abstinence from highly palatable foods for the management of weight during menstruation could also be the reason for such irresistible craving [45,47]. It was also studied what kind of age groups desired chocolate more. A research conducted with 89 white people in the age group from 18-64 was given a questionnaire and it was found chocolate consumption influenced age groups, The younger ages from 18-24 consumed more chocolate. This leads to a speculation that the younger ages provided internal cues for consumption of chocolate more than the older people [48].
FIG 2. A summary of mechanisms hypothesized to play a role in the etiology of perimenstrual chocolate craving.

Adapted from Hormes, J. M. [47]

XI. EMOTIONS AND BEHAVIOURAL ASPECTS OF CHOCOLATE

So far how chocolate initiated the craving and why one feels to eat more was detailed. It was also discussed that chocolate produced euphoria, a sense of pleasure and satiety. It is believed to be an aphrodisiac. Some consider eating chocolate as an antidepressant and stress buster. Chocolate indulges one in a lot of memories. There are many positive aspects associated with the consumption of chocolate and not forgetting the negative emotions like guilt, disordered eating leading to unnecessary weight gain. There are many aspects of emotions and behaviours that is connected with the consumption of chocolate.

When a research conducted to check the states of emotion when women were asked to consume either chocolate or an apple. Consumption of both filled their hunger. It was observed that women who consumed chocolate had a positive emotion due to chocolate’s sensory property. But that was instantly followed by negative thoughts like guilt [50]. This proves that consumption of chocolate did have an emotional uncertainty. Table 2 mentioned below gives a relation between chocolate and negative mood. Another study that took place to test the effects of chocolate on experimentally induced mood states suggested that negative mood was reduced to chocolate consumption compared to drinking water. Chocolate played a major role in improving one’s negative mood. This applied only to palatable chocolate and not the unpalatable one. This proved that palatability was the major cause of the mood states and it was reported that mood alteration lasted only 3 minutes [51]. When one believes that chocolate consumption relieved stress or worked as an antidepressant, it may be true that chocolate offers a respite, but it expands rather than abbreviate one’s dysphoric mood [14]. When we consider craving as an emotion. Numerous studies represented that those withstood cravings experienced positive mood [52]. According to Liebowitz and Klein, who suggested during the state of depression, depressed people binged on chocolate though his theory was proved wrong, but craving during depression could be better reflected by homeostatic approaches in a way to bring your stable emotions back [16]. There is also something called “emotional eating” or “stress eating”. Stress eating can be simply explained as consumption of food that is basically driven by emotions like stress even in no presence of hunger. It is interesting to know comfort food is taken to beat the stress. Comfort food and the release of stress are interlinked, this is known by our body’s release of cortisol (stress hormone) [53]. Findings by Oliver et al showed that, stress induced one to intake of chocolate cake, sweet fatty foods and this was mostly applicable to “stress eaters” [54]. Talking about the behavioural aspects of chocolate, it is a known thing that chocolate is a hyper-palatable food. Several studies supported that just like drugs of abuse even hyper palatable foods stimulated dependence [53]. Again, comparing with addictive drugs, even palatable foods, activated reward centres leading to release of neurotransmitters like dopamine, opioid, endocannabinoids which was being already discussed leading to producing reinforcements behaviours [55,56]. These reward centres in the brain creates an neurological adaptation, which in turn cultivates compulsive way of disordered eating and when one acquires a behavioural learning that consumption of foods like chocolate is the best way to abate long term stress, one infact may be considers “addictive” to it [57]. A study also found food choices made my people weren’t just by liking but also by the emotions evoked [58]. Few studies explained the positive effects of eating chocolate and few on its negative aspects. All the moods caused by eating chocolate were considered to be ephemeral [59]. Negative mood are considered, with explanations, in relation to other emotions and to chocolate eating are summarized below [7].

TABLE 2. Key features of negative mood are considered, with explanations, in relation to other emotions and to chocolate eating

<table>
<thead>
<tr>
<th>Key points</th>
<th>Explanation</th>
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<tr>
<td>Mood, emotions, and affect</td>
<td>These terms are often used interchangeably; however, emotions are usually considered to be caused by some event, such as obtaining a reward, or</td>
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leading to people conferring themselves as chocolate addicts leading to disordered eating ending up in guilt and weight management issues. So it is important to control cravings in order to prevent oneself from disordered eating. Is there any proved ways to reduce this dreadful craving for chocolate? It was clear that one of the reasons for craving chocolate is the neurotransmitters in the brain that producing internal cues increased reward centres. So when a study conducted on individuals to look at the picture of the chocolate, there was an activation of the reward centres inducing craving and when the participants were made to look at the same picture for more than an hour, though there was no extinction of craving but there was a major reduction in craving. This supported that the craving cue exposure with response prevention (CERP) influencing neural activity by magnetic resonance imaging controlled craving cues [60]. When it comes to craving, we have two kinds of memory. One is visuospatial and the other is phonological. Another study suggested that craving can be minimized by loading visuospatial memory, like clay modeling decreased chocolate craving [61]. There was again a study that proposed the idea of inhaling a non-food odourant to prevent chocolate craving [62]. These identified ways did succeed in proving to curb chocolate craving.

**REFERENCES**


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Adapted from Gibson, E. L. [7]


28. IPCC (1998) Principles governing IPCC work, Approved at the 14th session of the IPCC.


36. Kohler T, Maseli D (2012) Mountains and Climate Change-From Understanding to Action, third ed. Published by Geographica Bernensis with support of the Swiss Agency for Development and Cooperation (SDC) and an International Team of Contributors. Bern, Switzerland.


40. Long et al., (2006) Recent research in the crop modelling school has cast doubt on the magnitude of beneficial effects from CO2 fertilization.


52. Scenario A2 is the second highest emission scenario among the six scenarios considered by the Third and Fourth Assessments Reports of IPCC. Cline (2007) argued that scenario A2 should be viewed as an intermediate emission path as IPCC scenarios are biased towards underestimation of the future emission.


58. Thu C, Neefjes K, Huong TTT, Thang NV, Nhan MT, Tri LQ, Thanh LD, Huong HTL, Son VT, Thuan NT,
