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Yellow Dragon, Green Belt and Alternative Ecosystem States

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Abstract

This note briefly discusses different aspects of dust storm and issues surrounding the Green Belt Eco-Strip National Program (GBESNP) initiated by the Government of Mongolia in March 2005. Increases in dust storm intensity and magnitude might be an indicator for deteriorating ecosystem states. If there is such an increase, it is only a consequence of unsustainable resource use by humans, including proximately the overgrazing, mining, agriculture and deforestation and ultimately climate change. Additionally, the effects of dust storms are not all bad, but there are other aspects of it that should be considered when one wants to address the issue. Apparently, dust storms play an important role in global circulation of nutrient and minerals as they have always been. Thus they do have positive effects in ecosystem states elsewhere on Earth. It seems however these other effects of dust storms are largely ignored. The note also points out some of the important theoretical and practical aspects that need to be seriously considered before taking on such a large scale environmental engineering effort as GBESNP. If dust storm is increasing in frequency and magnitude, it is crucial to pinpoint causative factors and implement efforts aimed at improving and enforcing laws and regulations on those causative environmental practices. Acting before thinking is not the smartest habit and we have reasons to believe that implementing the GBESNP (with its name basically copied from elsewhere) without good plan and management is not a solution, but it may even add to the problem. Therefore, we urge environmental managers and scientists, especially policy-makers to seriously weigh the pros and cons of the project. If policy-makers seek a short-term public relations benefit from a largely uninformed general public, it is the scientists' obligation to intervene.

Key words: Green Belt Eco-Strip National Program Project, dust storm, iron hypothesis, cause and consequence, alternative stable states, Environmental Impact Assessment,

The fifth season or yellow dragon, is it all bad?

Each spring, soil particles from the Gobi Desert, which spans over Mongolian and Chinese political boundaries are swept up by a cold air mass called the Siberian High into the atmosphere and blasts into south east China, Korea, and Japan, sometimes even reaching to islands in the Pacific Ocean and west coast of North America (Wright, 2005). On rare occasions, it can go even further. The 1998 dust storm moved as far as over the continental US to eventually move off the East Coast into the Atlantic. The Koreans call this phenomenon the "Fifth Season" (or "Yellow Sand") and the Chinese call it "Yellow Dragon" (Ratliff, 2003). Although coarse sediment materials such as sand particles soon fall out, finer silts and clays can ascend to 5,000 m and travel thousands of kilometers. At its peak, the dust storm assaults cities and rural areas not only causing safety issues (decline of visibility), but also health concerns (a major peak in number of patients suffering from respiratory ailments and potentially infectious disease agents and polluters carried with it; Vedal, 1997; Nel, 2005; Pelletier, 2006), and environmental problems (pollutions, soil erosion, desertification etc.). The dust storm also creates major economic and social problems as it shuts down airport operations, damages or destroys crops to impoverish residents and clogs fine machinery (Ratliff, 2003; Wright, 2005). As such, it is declared as a natural disaster in Korea. Overgrazing, deforestation, mining and drought are to blame as these proximate factors cause the upper layer of the soil to become mobile so they can be easily picked up by the wind. The Central Asian Gobi desert expands at a rate of some 2,500 square kilometers per year, according to some sources (Ratliff, 2003).

The above is what people think or rather are told by mainstream media, and that this is all bad. There is also another side of the fifth season which can be seen as positive. It is well known that dust storms play an important role in global ecology and they have been an important link in the global nutrient cycling among different domains of biosphere for as long as there have been continents, soils, waters and air. First of all, nutrient supply rate by the dust storms seems to be a vital factor in maintaining some of the most interesting and diverse areas on the world. Research showed that as much as half of the fine soils on the Colorado plains are supplied by dust blown from the Mojave Desert which brings the essential nutrients and trace minerals necessary for plants (Wright, 2005). Similarly, the Caribbean and Hawaiian Islands, which are rocky islands but yet with amazing diversity of organisms, receive nutrient rich soil from the Gobi Desert transported by dust storms (Shaw, 1980; Duce *et al*., 1980). Studies as early as in 1960s and since also determined that Hawaiian Islands, for example, receive significant amount of dust or soil particles which are crucial in those nutrient-poor ecosystems (Wright, 2005). Therefore, one can argue that some of the most important biodiversity areas are sustained by nutrient inputs from the Gobi Desert to a certain extent.

The link between ocean productivity and dust storms has also been known for some time now. It was in fact the basis of the so-called 'iron hypothesis', which speculated that open ocean phytoplankton productivity was limited by iron deficiency and dust storm cycles may have caused glacial-interglacial cycles by increasing iron input into the open ocean, which caused phytoplankton blooms. The algal blooms in turn may have caused a greater uptake of atmospheric CO_2, the main greenhouse gas responsible for trapping the heat, leading to cooler periods of time (Martin, 1990; Kohfeld *et al*., 2005). Meskhidze *et al*., (2003, 2005) also reported an important link between ocean productivity and dust storms, and even atmospheric pollution. There is no question that dust storms are one of the major sources of limiting-nutrient inputs to the open ocean systems (Bishop *et al.* 2002). However, iron sources in the dust are not readily available to phytoplankton because iron needs to be in a soluble form to be used by phytoplankton. Since the open ocean phytoplankton are limited by iron availability, an idea was developed to take advantage of just that to reverse the greenhouse effect: "fertilizing open ocean systems with iron to cause phytoplankton biomass bloom, which in turn will take up more CO_2 from the atmosphere." This idea was proposed and tested several times in open-ocean experiments. It is true that several-fold increases in phytoplankton biomass were observed in fertilized ocean water (Coale *et al*., 1996), and Southern Ocean Iron Fertilization Experiment (SOFeX) Project is doing exactly these kinds of experiments to test whether iron fertilization can be a solution for decreasing the CO_2 level in the atmosphere. This has a potential to develop into a negative cost business, the idea that is highly controversial. Possible consequences and efficiency of such large-scale environmental engineering projects draw skepticisms, and rightly so (Fuhrman and Capone, 1991; Peng and Broecker, 1991; Jickells *et al*.; 2005). The point here is that the nature has been doing what people are thinking about doing now for probably countless thousands of years.

Therefore, we would argue that the dust storm has been an important part in a larger scale nutrient circulation to help maintain many terrestrial and aquatic ecosystems. As long as there has been the life on earth, there were undoubtedly storms and winds that brought nutrients and minerals to the open ocean and other less fertile lands. Thus, the occurrence of dust storms is not always bad globally, when they are at moderate level. We should also point out at the insufficiency of perfectly convincing evidence and long-term data about the intensity and magnitude of dust storms and their rapid increase in recent years that would well correlate with warming and other disturbing global trends beyond reasonable doubt. The other side of the story may be that people's tolerance level to the environmental conditions has also decreased, contributing to even more subjective conclusions that dust storms have been increasing. This could be especially true when countries in South East Asia that are on path of dust storms from Central Asia have recently become major worldwide manufacturers of pollution-sensitive electronic goods such as computer chips, making them less and less tolerant to contaminating dust particles. However, we do suspect that the extent of dust storm from the Gobi Desert is increasing and it is an indication of increased desertification rate. Historical accounts of the Asian dust storm come from as early as 1200s, i.e., the dust storms have been happening for a long time. The 8th Special Session of the Governing Council of the UN Environment Programme and the Global Ministe-

rial Environment Forum concluded that the scale and intensity of North East Asian dust and sand storms have increased (UNEP, March 2004). No matter how people see the dust storm, they should not forget that most of what is in media is only one of the *consequences* of much larger environmental problems. If people want to decrease the extent and magnitude of dust storms, then they will have to target their *causes*, which lie very much at the heart of the environmental practice and policy (see Geist and Lambin, 2004 for a meta-analysis of factors contributing to desertification).

Green Belt Eco-Strip National Program

In March 2005, the Government of Mongolia gloriously announced an ambitious campaign called the Green Belt Project (the official translation is Green Belt Eco-Strip National Program, and hereafter GBESNP and see Government Resolution #44 dated as March 9, 2005). Superficially, it may sound as a creative idea, but we should point out that this is nothing more than a Mongolian adoption of China's Green Great Wall Project, which started in 2003 as the fourth phase of a massive afforestation program launched in 1978 with similar purpose and, of course, this initiative by Mongolian politicians is not the first in its kind as there have been many others with varying success (or failure) around the world. In about 1935, overgrazing and drought caused close to a billion tons of topsoil to be blown away from the Southern Plains of USA, creating the Dust Bowl. To solve this problem, the newly formed Soil Conservation Service introduced the Shelterbelt Project - a 180-km-wide strip of trees that divided the country from Canada to Texas. In a few years, it helped to reduce the amount of airborne soil by 60% (Ratliff, 2003). But some areas are too arid to start with and in many cases trees do not grow. Even if they do, they take up too much of groundwater and worsen the problem (Ratliff, 2003, Wright, 2005).

Except for the fact that it was being implemented by the Government of Mongolia and the Prime Minister will be in charge, the full details of how the Mongolian GBESNP will proceed are still not available. How will it be funded, how will scientists from different fields be involved in it, how will the decisions to afforest some areas but not others be made, how will irrigation and other issues be resolved, what species of trees and other plants will be used and what are the pros and cons of the project? According to the National Program affirmed by the Government of Mongolia in March 2005, the Green Belt will be more than 2,500 km long and at least 600 m in width to cover 150,000 hectares of area in the desert, semidesert and steppe zones. It will be a large-scale, multi-year undertaking (up to 30 years for completion of at least 50% of total work, according to the Government Resolution). Within this framework, participation from government institutions, private sectors, NGOs and citizens to be responsible for afforesting sections of the Green Belt would be encouraged, and in addition to state and local budgets, a wide-scale public donation campaign to raise funds would be launched. Plantation of trees, bushes and fruit trees and irrigation of the area of the Green Belt would be synchronized. Large scale public awareness campaign about the program would be launched. The government has also encouraged planting trees at any ceremonial events and instructed people to use scheduled rotational pasture use during the cultivation stages. The government officials declared that the GBESNP would "solve the problem of dust storm and contribute to reversing global warming." However, the iron hypothesis and findings from testing the hypotheses mentioned above argue otherwise.

What the government officials say all sound to be convincing, but is this project necessary? The idea of the GBESNP was so well advertised and most of the general public probably believes that it is a good and important effort. Even some of the biologists, especially forest scientists appear to believe in the project. We will hereafter discuss some of the issues people need to be aware of before becoming staunchest defenders of the project. In other words, people need to learn from and listen to ecologists.

Alternative ecosystem states

All ecosystems are subject to gradual changes in environmental factors such as climate, nutrient regime, habitat fragmentation, landscape degradation and biotic exploitation. Usually, it is assumed that an ecosystem responds to gradual change in a smooth way. However, studies on semi-arid grasslands, freshwater lakes, coral reefs, and kelp forests have demonstrated that this is not always the case and gradual shift can be interrupted by sudden switches to an alternative ecosystem state (Dublin *et al*., 1990; van de Koppel *et al*., 1997, 2004; Scheffer *et al*., 1993, Carpenter *et al*., 1999, van Nes *et al*., 2002; Chase 2003; Hughes, 1994; Simenstad *et al*., 1978). Many diverse events such as

disturbance, environmental engineering, stochastic events and stressful abiotic conditions can trigger such an abrupt shift.

The idea that an ecosystem can switch to an alternative equilibrium state was developed in theoretical models (Holling, 1973; May, 1977). Such a shift between alternative stable states can be graphically demonstrated by the models of multiple (or alternative) stable states (Figure 1A, see the figure caption for explanation). The message from all this is that once an ecosystem is pushed to another stable state, it is much harder to restore the original state. Even very small perturbation can push the system over the boundary between the basins of attraction.

What does this have to do with the GBESNP? Scientists hypothesize that a wide variety of small changes such as grazing, evapotranspiration and other perturbations in Mongolia could cause abrupt shifts between steppe grasslands and forests or between grasslands and desert (Figure 1B). For example, if the recruitment of larch seedlings depends upon the presence of adults this may cause a steep threshold. It is possible that adult trees may increase recruitment of seedlings by limiting desiccation stress and a critical minimum number of adult trees may be needed for any improvement in forest recruitment causing "an all-or-nothing effect". This critical number of adult trees may itself depend on environmental conditions. If the threshold is steep enough, this system will show a bifurcation fold and hysteresis (Petraitis and Dudgeon, 2004). For example, the species composition (steppe grasslands vs. larch forests) could then show a discontinuous shift, a bifurcation fold, with even a very small change in rates of evapotranspiration due to any disturbance, which is driven by grazing pressure and global warming. Moreover, grasslands or forest cannot be recovered by small reversals in grazing pressure or warming trends. In other words, the system has "memory" and thus exhibits hysteresis. It just demonstrates how difficult it might be to restore forests once we lose them. Similarly, it may be difficult to restore grassland ecosystems if desert ecosystems have already been established.

The other side of the story is that a large scale environmental engineering project such as the GBESNP may push ecosystems into a lower state by introducing additional perturbations. The already-fragile soil of relatively pristine grasslands can easily be disturbed and abruptly shift to a lower quality alternative equilibrium and it cannot be reversed by small reversals in the human-made disturbances. It is important not to make any change without understanding the mechanisms of ecosystem functioning, even if the intentions are good. GBESNP-defenders may even worsen the Yellow Dragon problem without knowing. Therefore, the pros and cons of the GBESNP must be carefully considered.

There are other reasons why forestation may not work for some species of trees in some grassland ecosystems. To understand why, one has to look underground and find out whether grasslands (or deserts) influence the soil mycorrhizal communities in ways that are detrimental to re-establishment of tree species. Mycorrhizal fungi form mutualistic associations with plant roots, benefiting the plant primarily by facilitating nutrient uptake (Smith and Read, 1997) and receiving carbohydrates in return. The two most common types are ectomycorrhizae (ECM), which are exclusive to woody plants, and arbuscular mycorrhizae (AM), which are common on herbaceous species and less common on woody species. Because of the different mycorrhizal associations in different plant groups, the composition of the plant community can impact the composition of the fungal community in ways that feedback to affect the success of other plant species (Read, 1990; Brundrett, 1991; Francis and Read, 1994; Northup *et al*., 1995). Since grasses typically form AM (Smith and Read, 1997), it is likely that the ECM necessary for the success of trees are absent in grasslands and sparse or absent at the forest-grassland ecotone. This idea is still needed to be experimentally tested before spending money to grow trees.

Thus it appears that the GBESNP may even be *detrimental* to already fragile arid ecosystems by pushing them over the boundary of basins of attractions (see Figure 1A) as it will introduce further perturbations. And there may even be a good empirical reasons why trees may not grow at all in some grassland ecosystems because certain tree species need to be associated with ECM, which may be absent in areas where the GBESNP plans to cultivate trees.

Will the GBESNP work: cautionary note

The foremost goal of the GBESNP is presumably to decrease the extent and intensity of the Yellow Dragon and desertification processes. Even some scientists seem to buy into to this idea, but can politicians guarantee its success? Before taking on this massive environmental engineering effort, one must carefully consider all possible scenarios. We

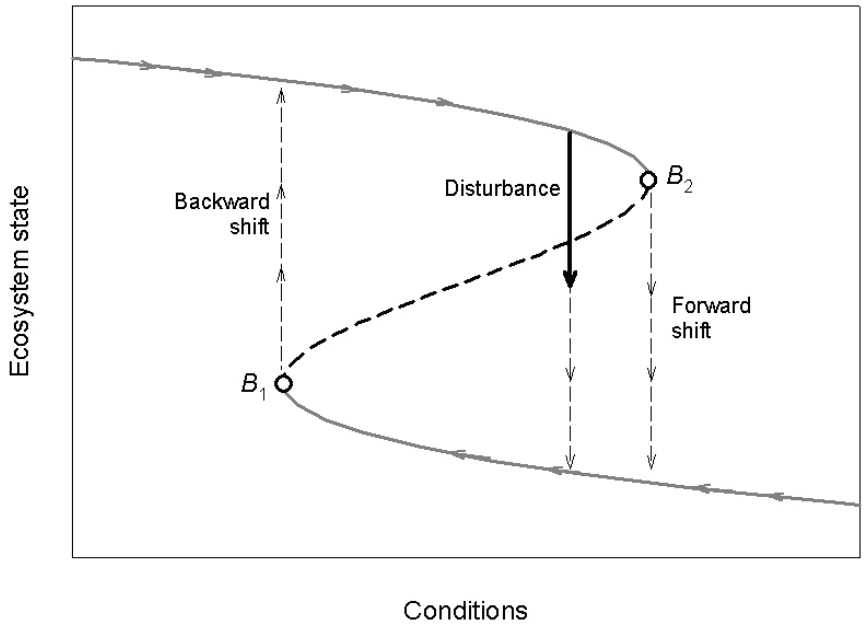

Figure 1. (A) Ecosystem equilibrium state and two possible ways of shift between the alternative stable states. Ecosystem equilibrium state is shown as two saddle-node bifurcation and there can be three equilibrium points for a given condition. In this case, the middle section (dashed portion) is unstable equilibrium and represents the boundary between the basins of attraction of two alternative stable states (B_1 and B_2). First possible way of state shift is driven by change in condition. A slight increase in conditions may bring the system that is on the upper isoclines beyond the bifurcation point B_2 and induce a catastrophic shift to the lower alternative stable state (forward shift). A backward shift can occur only if conditions are reversed beyond the lower bifurcation point B_1. Second, large enough disturbances (thick arrow) can also push the system over the boundary between the attraction basins, causing a shift between alternative stable states (modified from Scheffer *et al*., 2000, 2001; Scheffer and Carpenter, 2003). (B) Forest and steppe zones (or steppe and desert) can be hypothesized as two alternative stable states. Within this framework, the steppe can be seen as a disturbance-driven basin of attraction caused by deforestation (fire and logging), overgrazing and warming. Changing forest into steppe is much simpler than changing steppe into forest. Similarly, grassland and arid land can be considered as alternative ecosystem states (Photo courtesy of L. Ariuntsetseg).

have discussed above some theoretical reasons why we need to be careful about the GBESNP and now we will address empirical aspects before starting to turn soils all around the country, at tax payers' expense.

It should be pointed out that the above-mentioned Chinese Green Great Wall project started on the basis of already existing man-made structure which is to cultivate plants along the 1,110-kilometer-long Qinghai-Tibet Railway on the Qinghai-Tibet Plateau. That is, Chinese the country with their share of failures in anti-desertification efforts are attempting to alleviate man-made disturbances which had already been caused by building the railway. Now the Chinese plan to create approximately 4,500 km long network of forest belts in areas where the ecosystem states have already degraded. On the other hand, GBESNP in Mongolia will involve cultivating plants in relatively undisturbed areas, including some of the most important ecosystems; quite different. It will perhaps change some of these areas forever by cultivation of various plants and other changes associated with it. In a sense, the GBESNP will only add to the disturbance of ecosystems by tilling and sowing the soils making them easily available for wind pickup and dropping the water table, which could be sufficient enough perturbation to push the ecosystem to a lower state. It clearly demonstrates a disturbing trend in environmental policy-making in Mongolia. Defenders of the GBESNP claim that there is a great deal of interest from outside to support the project. One has only to mention that despite great efforts to raise donor funds from outside sources, the only government showing any interest so far is North Korea.

One important point is that the GBESNP has to be a subject to environmental impact assessments (EIA) and cost-benefit analyses by independent scientists and agencies before it starts. Just because the Government initiated it, it cannot cast aside environmental laws and regulations of the country. So who, if anyone, is doing the EIA? A brute force approach almost never works: one does not open up a clock with a hammer without understanding what intricate parts interact inside the clock to make it work. Ecological systems are much more complex than a clock, it is hard enough to predict what consequences will emerge as a result of any environmental project. Such a large scale project as the GBESNP should have flexible, adaptive management plans that took all possible twists and turns into consideration, even if it is initiated. Has everything been thought out?

Given that independent assessments are carried out and they agree that the GBESNP should be implemented, another question arises: "what species of plants should be grown and where?" This is also a serious issue that should be approached carefully, especially when the item 2(b) of the Government Resolution dated March 9, 2005 clearly instructed to look into possibilities of growing exotic plants (while the Appendices 3 and 4 have listed schematics about what trees and bushes should be planted). Ecologists have long known and tried to deal with effects of invasive alien species in native communities, which is a world-wide problem (Mack *et al*., 2000). Is it going to be repeated in Mongolia? Who decides what species to plant within the Green Belt? One of the well-known effects of introduction of non-native trees on ecosystems is a change in biodiversity caused by hydraulic lift. This usually has a negative effect on native species by encouraging other species to grow and this eventually leads to further drying off of areas. Such plant (or tree) species usually have deep-penetrating roots and are superior competitors which drive the groundwater table even deeper such that native plants can no longer tap the water they need. Another question is "who is going to look after the seedlings once they are planted?" So far, nobody was responsible once some seedlings are planted (Figure 2). Domestic and wild animals will easily take them unless there is an expensive and maintained fence. Do they plan to create exclosures at the initial stages of the project, which will inevitably serve as obstacles to the movement and behavior of wild animals. Even without closures, planted seedlings could potentially serve as a barrier for some animal species, disrupting movement routes. Who has judged potential effects of such isolation or fragmentation? If the Green Belt is to cut across Mongolia, it will inevitably pass through protected areas. Who has authority to change those rare ecosystems by planting trees or other plants?

It is possible the GBESNP may be successful without any negative effects on ecosystems. But we should point out again that it is always far more effective to deal with causes than dealing with consequences. It is important not to combat dust storms themselves, but to focus on the factors that cause the dust storms. Instead of trying to add to man-made changes all around the country by implementing the GBESNP, the government should

Figure 2. These pictures document the failure of afforestation efforts as part of the Green Belt Eco-Strip National Program. Although government officials claim 60-90% success rate for the GBESNP in various parts of Mongolia, the actuality reveals nothing more than complete failure and irresponsible budget expenditure. Although there is nothing about planting coniferous trees in the Government Resolution #44 dated March 9, 2005, these pine seedlings were nevertheless planted in this part of the Green Belt and virtually none grew. The pictures were taken in Undurkhaan Soum, Hentii Aimag, in July 2005. "Green Wall" is written in Mongolian on the tank in the middle picture (Photos by B. Bayartogtokh).

Figure 3. Two of the examples of many "empty gardens" in the streets of Ulaanbaatar city where the newly planted trees and other horticultural plants suffer and fail to survive due to lack of maintained care and support. (Photos by B. Bayartogtokh in Bayangol District, June 2005).

be encouraging changes in environmental practices to alleviate the problem. Mining companies should restore after extraction, herders should learn to use the land in a sustainable way, timber harvesters should implement reforestation project and everybody else should be environmentally aware and play their part as far as possible. Those are some the practices that the government must make sure are happening.

Side note for the public

Since taxpayers are the ones who will ultimately finance the GBESNP, a massive undertaking, they have the right to ask questions such as "on what empirical basis does the government think it will really work?" and "who will be accountable for failures?" i.e., if it further deteriorates already susceptible ecosystems and push them to lower alternative states? And who will be responsible if species introduced

as part of the GBESNP causes local extinction of rare species of native animals and plants? Could it be nothing more than a political propaganda? We must point to a meta-analysis that showed one of the most prominent underlying driving forces for desertification involved national environmental policies (Geist and Lambin, 2004).

Before we start becoming true followers of the GBESNP, we have to recall the fact that all Mongolian governments in recent years have not even been able to grow enough grains and vegetables (production has been decreasing consistently over the years) and the forestry sector is in disarray (World Bank, 2004). Another fact is that we cannot even maintain gardening in the capital city as the most of newly planted trees and other horticultural plants do not grow well although they are under support and supervision of the city architects and gardeners (Figure 3). If we cannot maintain national level agricultural yields and the horticultural plantations in the capital city at a reasonable level, are we prepared to experiment with an afforestation program, which is a more challening task with some risk? Let us also remember that the Mongolian Government claimed, and publicized to exhaustion, that they planted a million tree saplings in the spring of 2005. Unfortunately, it will take only a short visit to Bogd Khaan Mountain to witness that not many, if any, of the trees the government officials ceremoniously planted have actually survived. A similar fate awaited most trees planted alongside the Millennium Road (see Figure 2), which is another grand national plan. We have all personally witnessed dead trees in both cases. Politicians were seen everywhere when those saplings were planted, but later they were nowhere near the dead trees. Reminded of these facts, are we, as taxpayers, convinced enough to authorize them to use our budget to grow trees in areas where there are no trees (especially when they could not even grow trees in already-forested Bogd Khaan Mountain)? Nobody has a right to bury taxpayers' money without likely positive results. It is important to look at the results gained, but not at propoganda.

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