An virtual numerical experiment to understand the impacts of recovering natural vegetation on the summer climate and environmental conditions in East Asia

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Abstract **By applying a regional integrated environmental model system (RIEMS), a virtual numerical experiment is implemented to study the impacts of recovering natural vegetation on the regional climate and environmental conditions. The results show that recovering the natural vegetation in large scale could have significant influence on summer climate in East Asia. Not only would it be able to change the surface climate, but also to modify to certain extent the intensity of monsoon circulation. Although this is a virtual experiment at an extremely ideal condition, the implication of the simulating results is that the on-going nation-wide activities to recover the crop land for forest and pasture must be managed according to the local natural climate, hydrological and soil conditions. Only under such a condition, would the recovering of natural vegetation bring about significant climate and environmental benefits at regional scale.**

Keywords: vegetation change, East Asian monsoon, regional climate simulation, virtual experiment.

Both the observational and theoretical studies have proved that the destruction of natural vegetation cover, such as destructive lumbering of forests and over-cultivation and over-grazing of grassland has been one of the major causes for the deterioration of regional climate and environment[1—4]. In order to improve the living environmental conditions, human society is now taking a series of measures to adjust its own behavior, such as stopping the destruction of forest and grassland, slowing down the over-expansion of agricultural land and converting the agricultural land for forest and pasture. There is now a great concern for how to implement such approaches scientifically so that the ecological benefits can be realized more effectively.

A basic principle to implement the policy of converting the agriculture land for forest and pasture is that the consequence of all activities must meet the requirement of long-term sustainability of the ecosystem and environment. Therefore, the human society must adjust its own behavior by reducing the disordered human activities and organizing more ordered activities. That means the overall programming of economic development, including farming, forestry, animal husbandry and industry, has to be based on the natural conditions of climate, hydrology and soil in the region. To meet the requirement of sustainability, it is strongly recommended to design the reasonable land use schemes. The most ideal scheme is to convert all the land cover into natural vegetation most suitable for the local climate.

In this note, a regional integrated environmental model system (RIEMS)[5] was used to simulate the impacts of recovering natural vegetation over East Asia on the regional climate and environmental conditions. This virtual experiment aims to investigate whether the implementation of the policy to convert the agricultural land for forest and pasture at large scale would be able to produce significant ecological benefits. In the meantime, this study will provide scientific bases in the management of ordered human activities.

1 A regional climate model and experiment design

The model used for this study is the Regional Integrated Environmental Model System (RIEMS) which consisted of an atmospheric dynamic model (MM5), a radiation scheme (CCM3) and a land surface scheme (BATS1e)[5]. Validation of the model performance has shown reasonably well results in its capacity to simulate the regional climate in East Asia[6]. Two vegetation cover data sets were used in this virtual experiment. One is the current vegetation (V_c). It is from the global land cover classification data for 1987—1988 and is part of the Global Data Sets for Land-Atmosphere Models, ISLSCP Initiative 1, 1987—1988, developed in the International Satellite Land Surface Climatology Project (ISLSCP)[7]. So far, this is the most qualified land surface satellite data and has been widely used to represent the current condition of global vegetation cover. The data sets contain also other surface parameters, such as surface roughness, albedo and leaf area index and so on, used in land surface models. A 10-year data set is being planned to develop in 3 years. One has to realize that the actual current vegetation cover should have somewhat differences with the V_c for 1987—1988, but these differences are smaller than those with potential vegetation that is another data used in this experiment. Therefore, we assume that this vegetation cover data (V_c) can be looked upon as the actual current vegetation cover approximately.

Another vegetation cover data set is called natural vegetation. As it is computed by an ecosystem model based on only the mean climate condition, it can also be named potential vegetation (V_p). This data set was created in the land use/land cover study project for Temperate East Asia (LUTEA) with a biome-climate matching approach which is widely used in the international ecological science community. It is based on the mean climate of East Asia, but subtracting the agriculture ecosystems[8].

The main vegetation classification of this data set over East Asia is in good agreement with the natural vegetation maps.

Plate Ⅰ presents the changes from potential vegetation to current vegetation. Nearly 90% of the total area of this experiment show significant changes. The most pronounced changes occur in Northwest China where the grassland has been changed to semi-desert or desert, or semi-desert changed to desert, in East China where the forest has been changed to agricultural land, and in Southwest China where evergreen broad-leaf forest has been changed to shrub, etc. There are also significant changes in vegetation over Japan.

The virtual experiment is performed under the above two vegetation cover conditions. The RIEMS is integrated from May 1 to August 31 with the global observation (NCEP Re-analysis data) in normal year as the initial and lateral boundary conditions. The differential fields of integration by the two vegetation cover data sets (potential minus current vegetation) are used to represent the impacts of recovering natural vegetation since the two simulations are identical to each other for all the conditions, including the large-scale driving fields used as the initial and lateral boundary conditions, and the parameters of all physical processes except for the vegetation cover. In order to maintain the linkages between the large-scale environment and the simulated region, a relaxation scheme with 10 buffer zones is applied for nesting at the lateral boundary[9].

2 Main results

The comparison of the simulation results of two different vegetation covers shows clearly that the recovering of natural vegetation would enhance the summer monsoon over East Asia which would bring more moisture to a large portion of East China, resulting in the increase of atmospheric moisture content and precipitation as well as the soil moisture. These changes would improve the regional ecological and environmental conditions obviously.

Fig. 1 presents the changes of precipitation, surface air temperature, air humidity and soil water content in summer (June, July and August). Obviously, the precipitation increases in most of the eastern areas with a mean amplitude of 1—2 mm/d (fig. 1(a)), while the temperature changes in relatively small areas with a cooling of −1℃ in the North China Plain and eastern part of Northwest and with a warming of about 0.5℃ in other areas (fig. 1(b)). The increase of atmospheric moisture is most significant at the lower troposphere (850 hPa) with an amplitude of 0.5—1.0 g/kg per day covering the area from South China to the North China Plain (fig. 1(c)). The increase of soil moisture at the root depth occurred mainly in the area to the south of the Yangtze River and in the eastern part of Northwest China with an amplitude of 0.5—1 mm/d.

Fig. 2 presents the changes of atmospheric circulation in summer over East Asia. According to the fields of vector wind (fig. 2(a)) and geopotential height (fig. 2(b)) at 850 hPa, the deepening of monsoon depression over the southern part of the region causes more southerly flow to enhance the summer monsoon over that part of the region. Over the northern part of the region there is a differential anticyclone circulation located in the eastern part of the region, which is favorable for the transfer of moisture from the ocean to the inland arid and semi-arid region. These changes would certainly improve the environmental conditions over there.

To understand the mechanism of impacts of changing vegetation cover, fig. 3 demonstrates the changes of surface physical parameters related to different vegetation covers. In general, recovering the natural vegetation will increase the surface roughness (dark shaded area in (a)) and result in the reduction of surface wind over most of the region. It would also increase the leaf area index (dark shaded areas in (c)), but decrease the surface albedo (light shaded area in (b)) resulting in more radiation absorbed by the land surface. Less total evapotranspiration of vegetation-soil system would increase the water content of soil at the root depth. However, in the areas of cropland changed from forest, total vegetation coverage increased (dark shaded area of (d)). The whole story of changing surface energy and water budgets is rather complicated in the whole system.

3 Discussion and conclusion

The results of this virtual experiment indicate that the large-scale recovering of natural vegetation in East Asia would have pronounced impacts on the regional climate in summer, not only changing the surface climate, but also modifying to certain extent the summer monsoon circulation. This might be the evidence for the possible impacts of human-induced land use change on the earth system.

Of course, the above virtual experiment is an extremely ideal case. The scale of actual action to convert agriculture for forest and pasture cannot be so large and it is not possible to convert all the agricultural land in East Asia for forest. Therefore, the amplitude of regional climate change would not be as large as the simulated results. In the meantime, since the converting activities, in fact, would be rather dispersed, the integrated consequence needs to be studied.

However, the above virtual experiment implicates that the policy of converting agricultural land for forest and pasture and recovering a beautiful landscape with green hills and clear waters must be proceeded in light of local natural conditions. The natural vegetation covers over the region have to be used as a reference. In the present agricultural land of East China where there was forest biome, thus the climatic, hydrological and soil conditions over there are suitable for the development of forest. This

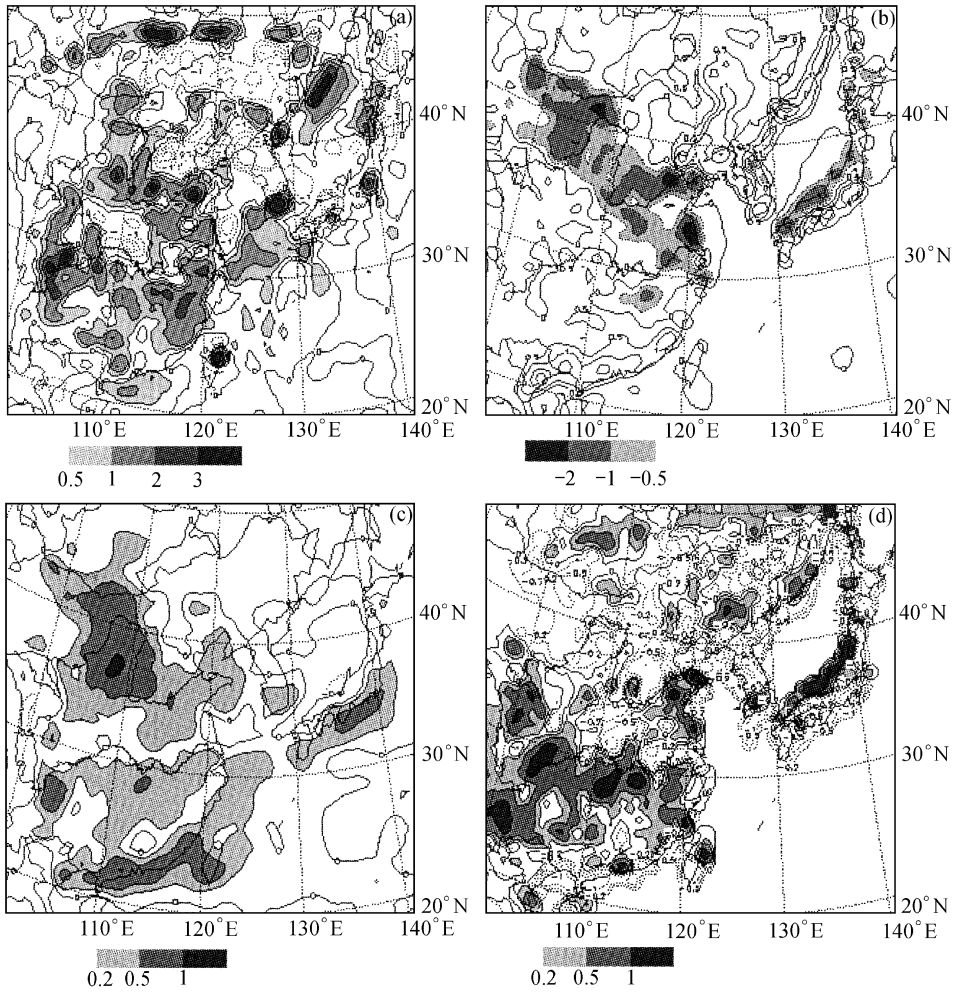

Fig. 1. Changes of summer climate over East Asia under two vegetation covers (potential minus current vegetation). (a) Precipitation (mm/d); (b) surface air temperature (℃); (c) 850 hPa specific humidity (g/kg • d) and (d) soil water content (mm/d).

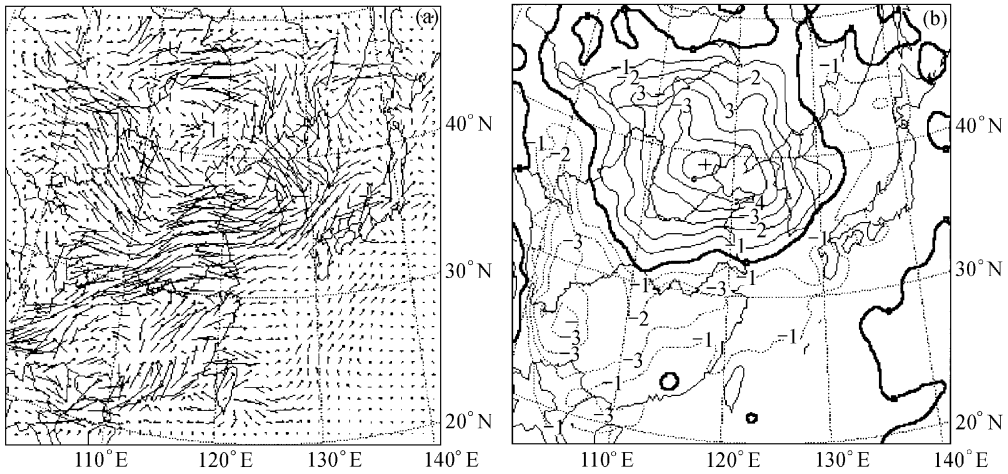

Fig. 2. Changes of atmospheric circulation in summer over East Asia under two vegetation covers (potential minus current vegetation). (a) Vector wind at 850 hPa (m/s); (b) geopotential height at 850 hPa (m).

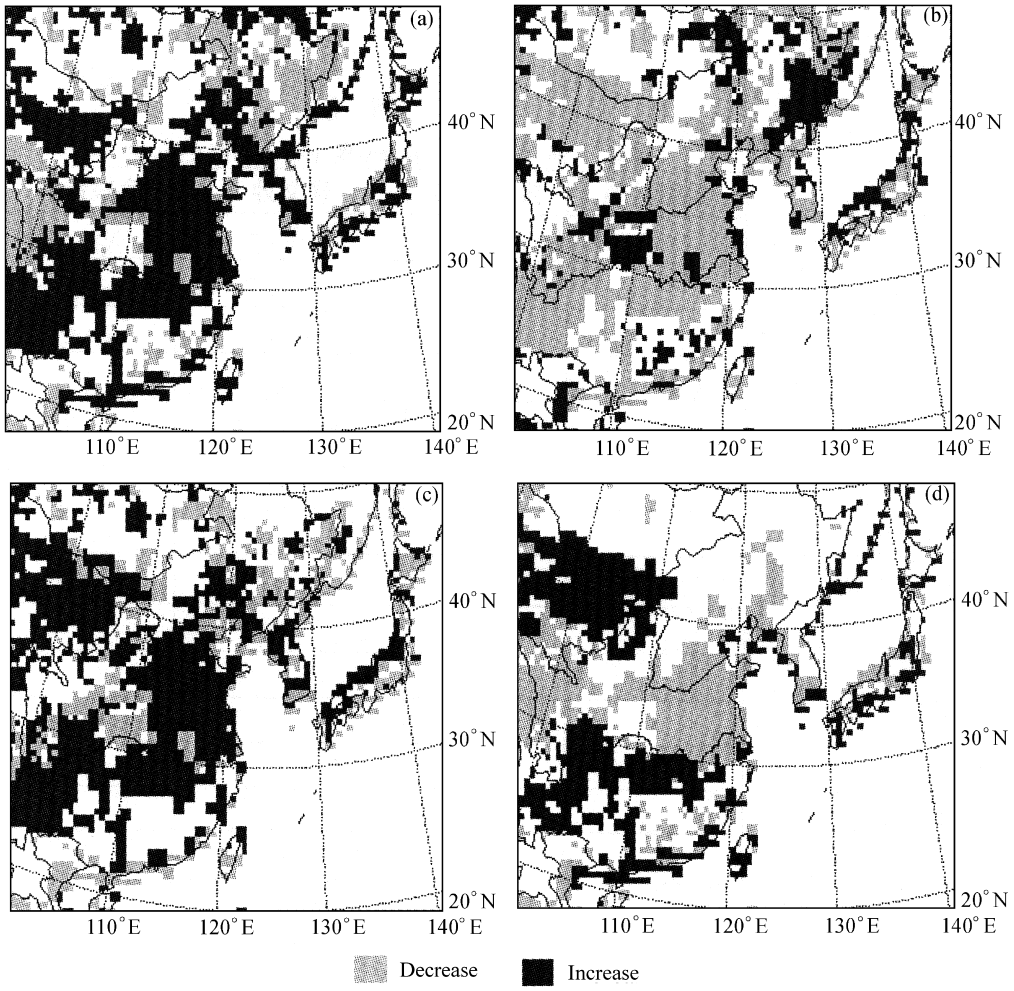

Fig. 3. Changes of four physical parameters of land surface under two vegetation covers (potential minus current vegetation). (a) Surface roughness; (b) surface albedo: (c) leave area index; (d) fractional vegetation coverage.

region should strongly be recommended for afforestation and increase of forest coverage on large scale under the condition to ensure the land for agricultural use. This region should be the first priority for building up the beautiful green hills and clear waters.

In such a region with rather rich water resources as in central western China where rather dense forests used to be there such as in Loess Plateau, the environmental deterioration is mainly due to the irregular human activities such as large-scale destruction of natural forests, and blind agricultural expansion which resulted in severe soil erosion. There would be more effective benefits in this region when the policy of converting agricultural land for forest and grassland is appropriately implemented. It should be pointed out that the improvement of ecological environment condition must follow the regulations of natural evolution of the ecosystems and must require a step-by-step long-term strategy. The enforced introduction of new species at an excessive speed would deteriorate the rather vulnerable environment by over-pressure from outside of the system.

As for the regions located in the natural zones of semi-desert and desert where the agriculture was developed under the so-called policy "self-supply of grain consumption" while completely relied on irrigation, it is no doubt that all the crop land over there should be converted into pasture in most cases. It is impossible and not reasonable to expect that this region will become a copy of "Southern China located in the North" with green hills and clear waters. It would be most reasonable at first to recover its natural conditions, even in a desert area and then to improve the environment over these regions through the long-term ecological process gradually. On the contrary, to violate the natural regulation would not restore the forest and pasture. The environment would not be improved, reversely it would be deteriorated. In designing a better scheme of the cultivation of forests and grasslands, the knowledge of atmospheric dynamics and thermodynamics and dyna- mics of ecosystem should be taken into account. In doing so, more carefully designed virtual experiments are needed.

This virtual experiment is a very preliminary one.

The physical processes of the model are far from complete and the parameterization schemes of these processes need to be further improved. The dependence of model results on the initialization and lateral boundary conditions need further examination.

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