

## The New Progresses in Coupling Relations of Mountain-oasis-desert System

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**Abstract:** In this paper, the concepts and principles of mountain-oasis-desert system (MODS) are put forward according to the natural geographical situations in arid zone of western china. The spatio-temporal characteristics and dynamic changes of typical MODS, the process of material circulation, energy transform and information transmission among MODS and the mechanism of MODS interaction and symbiosis are analyzed. The foundation and frame of the coupling type are determined by landform types and climate characteristics: the spatial pattern of the coupling type is determined by the hydrological characteristics; the vegetation type reflects the appearance of the coupling type; the soil state restricts the function of the coupling type and the human activities influence the development course of the coupling type. Interface course of MODS is closely related to such medium as water, soil, air, etc., and water is the major medium during the course of material circulation, energy transform and information transmission. The disorder of water salt, water heat and water land restricts the stability of water ecosystem.

**Keywords:** mountain-oasis-desert system (MODS), arid zone, hydrological process, interface, and coupling relation

### Introduction

The research in MODS coupling in western China is the major component in the project of "Comprehensive study in arid zone of western China", which is the 9<sup>th</sup> subject of the major project-"Regulation and evolution of the ecosystem in the arid zone of western China" (G19990435). This research targeted on the demand from Chinese government, emphasized to solve the major problems from national ecological and environmental emergency systems, and achieved great progress to support the ecological and environmental system construction in western China.

MODS coupling is a means to study the characteristics and the configuration course of the arid and semiarid mountain-basin system. The studies in ecotone among different systems (mountain, oasis and desert systems), especially in the formation and transformation of

water source, energy distribution and the transmission and feedback of different information, disclosed ecological course with different physical processes and biological processes on the system interfaces, and explored the sustainability of regional resources, environmental capacity, as well as the threshold and basis of ecological emergency. Based on above, by applying satellite remote sensing technology, combining geographic information system, we studied landscape frame of those three systems, analyzed their spatio-temporal structures and functions, and constructed the physical modeling adaptive to the interflow of material, energy as well as information in an arid or semiarid MODS. At the same time, we also set up the theoretical modeling for arid MODS coupling in western China, established pattern recognition methods in an artificial-natural coupling ecosystem, analyzed physiochemical properties between nature oasis and artificial oasis, and simulated water-salt balance point for the artificial-natural coupling ecosystem. According to the rules of formation, transform, consumption, preservation, as well as excretion of water resource, by combining the characteristics of vegetation and landscape, we studied different classes of watershed ecosystem in arid zone, and put forward construction methods, within which the major points are focused on the construction of water pathway, vegetation landscape, and oasis landscape, for watershed ecosystem. We further explained the basic evolution process of landscape ecology through the studies in the rules of climate change, and the water resource development and application as well as oasis evolution and ecological equilibrium.

The research in MODS coupling will provide a mirror to the international arid zone research. The theories and methods in MODS coupling, especially those functions in system coupling and their interface processes, are theoretically valuable in the comprehensive regulations of ecosystem, and the practice for ecological construction in the arid zone.

### Progresses of MODS coupling

#### 1. Studied the characteristics and general rules in the ecological coupling of arid zone

The characteristic differences in ecosystem coupling

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in arid area locate in hydrothermal situations, landscape spectrum, regional climate reactions as well as human activities etc. In the special region, the characteristics of longitude, latitude, altitude as well as underlying surface are basic essential elements to determine the characteristics of system coupling. Moreover, the modifications of the geographic parameters are major factors to distinguish the coupling relations and their belonging categories. In the process of MODS coupling, the characteristics of landscape and climate determine the basis and structure of the coupling; the hydrological properties determine the spatial structure of the coupling; vegetation type determines landscape appearance of the coupling; soil conditions restrict the functions of the coupling; as well as human activities influence the evolution of the coupling. Based on the theories and methods used in natural geography and landscape ecology, we studied the typical MODS coupling-“Kunlun mountain-Hetian oasis-Taklimakan desert” system and “Tianshan mountain-Fukan oasis-Gurbantunggut desert” system, and analyzed normal rules and modes of MODS coupling.

In the arid zone of MODS, the three major systems have their own characteristics and coupling relations between each other. Mountain system is the region to form water resource, the depot place to reserve mineral nutrition, and the resource pool for biological species; oasis system is the region with high productivity and labor source, and the survival and development center for human beings; and desert system is the region with extensive drought area with serious environmental conditions. To maintain ecological equilibrium in MODS is the basis of ecological construction and economic development in arid zone.

### **2. Described characteristics of material, energy and information coupling relations in an arid mountain-basin system**

Through the studies in spatio-temporal characteristics of hydrothermal, water-salts relations, vegetation, and soil, we explored the rules of ecological landscape in mountain system, distinguished the intrinsic relations of information transmission in mountain system, recognized characteristics in material circulation, energy transform and information transmission in arid mountain-basin system, and mastered

MODS ecosystem process in arid mountain-basin system. Mountain system provides rich particulate materials to basin system. And these materials are the basic materials to form the soil of oasis system. At the same time, mountain system transports a huge amount of surface and underground water to basin system. This determines the scope and scale of natural oasis, and influences the development potential of artificial oasis. Moreover, it constructs an interactive as well as cooperative macro-frame between oasis and desert in arid zone. MODS is embedded in a land with interference pattern. The components within MODS interact with each other and uphold the whole mountain-basin system in arid zone.

In MODS, very complicated mechanisms exist in the material transform in soil, water, and atmosphere, the information transmission accompanied with energy transfer, and the information transmission between mountain, oasis, and desert systems. The variation in the solar radiation influences the distribution pattern of organism and their corresponding environmental elements. Water is the major transport medium in processes of material circulation, energy transform and information transmission in nature. In processes of water formation, transform and consumption, they hydraulically connect with soil, atmosphere, and organism, and transports mass sand, mud, minerals and ions. Organism interacts with its environment and maintains its functions through the water regulation within and outside its body. The information transmission in soil is realized in the modification processes of natural environment and human beings' activities. The activities of irrigation, reclamation, fertilization as well as administration directly modify soil with additional information.

### **3. Analyzed spatial characteristics of oasis system in Xinjiang**

We analyzed MODS spatial characteristics determined by the landscape frame of “three mountains + two basins” in Xinjiang, explained the effectiveness of merging material, energy, and information together, the obviousness of the landscape mode, and the fragility of the ecosystem. We further put forward methods to establish oasis protective system, implement comprehensive monitoring and administration, and strengthen the fundamental

construction of oasis.

Oasis system is a synthetic body of nature and society, the objective for human activities in oasis system is to explore the potentials within natural resources and environments, and transform them into useful material, energy and information for the existence and development of human beings. At the same time, different feedbacks are obtained from the processes of economic and social activities. Just because of these feedbacks in oasis system, human beings can develop continuously by human and nature reactions to these feedbacks. We analyzed internal oasis system in the aspects of material flux, energy flux and information flux, and its relations to mountain system and desert system. This further helped us to understand the formation mechanism of oasis system and evolution rules, and provided theoretical and practical evidence for the continuous development of oasis system. Oasis system is a zonal landscape with a drought climate background, and its landscape structure and the spatial distribution of formation components are strictly confined by water pathway. The spatial structure and development scale of oasis system is confined regionally by natural factors as well as economic factors from humanistic community; so, oasis system is a synthetic product from the interactions of different factors. As a natural and economic system, oasis system is scattered or spatially separated in extensive desert areas. This situation finally determines the diversity, instability, as well as complicity of oasis system.

#### **4. Evaluated information characteristics in desert system**

Desert system is a relatively fragile, opening and nonlinear system in the state of non-equilibrium. The equilibrium of the system is maintained by adding negative entropy flow into the processes of continuous energy, material, and information exchange. Information flux within the desert system includes not only information from individual species, species group, and community, but also from plants, animals, and microorganism and their interactions. All of these endow desert system with rich properties. The information transmission in desert system between organism and water, between plants and plants, and between plants and animals is the major means to

maintain the normal operation and function of the system. So, information transmission takes an unsubstitutable role in the processes of development, maintenance, and evolution of desert system. So, to master the characteristics and whole process of information transmission in desert system is significant for the recognition of formation mechanism, evolution rule, and development tendency of arid environment, and for repairing the degraded ecosystem and recovering its system modeling.

#### **5. Disclosed water-salt coupling relations of water ecosystem in arid zone**

We summarized the appearance characteristics of water-salt coupling in the water ecosystem of Tarim River based on the analysis of spatio-temporal variations of water-salt in the main course of Tarim River: the volume of water restricts the spatial scope of water ecosystem; the quality of the water determines coupling type; and the discharge of pollutions influences the purity of the water. At the same time, we put forward methods to control pollutions within water ecosystem.

Water pollution in the water ecosystem of Tarim River is formed by social and natural factors. And the spatio-temporal variation of surface watercourse is the major reason to explain the variations in coupling relations. In the late 1950s, the mineralization was lower than  $1.0\text{gL}^{-1}$  in the upper-stream of Tarim River before its entrance into Taitema lake. Currently, the mineralization of the upper-stream of Alar is lower than  $1.0\text{gL}^{-1}$  only in July, August and October, but higher than  $3.0\text{gL}^{-1}$  in other months. The mineralization of the down-stream of Kala is mostly higher than  $1.0\text{gL}^{-1}$  except in March; it reaches the highest value of  $5.0\text{gL}^{-1}$  in July and December. From the water quality report, the pollution degree in Alar, Xinquman and Yingbazha is hung on the 5<sup>th</sup> level annually as well as Kala is hung on the 4<sup>th</sup> level. So, the water quality and hydrochemical constituent of Tarim River are the clearest symbols of water-salt relations.

The main course of Tarim River is seriously polluted. So, the fluctuations in water-salt relations, irregular hydrothermal, water-sand and water-soil balances strictly restrict the function and stability of water ecosystem of Tarim River. Then, the comprehensive measures as pollu-

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tion control, water quality improvement, and the maintenance of the stability of water ecosystem, are important strategies to regulate water-salt relations in water ecosystem, and pathways to construct the ecosystem in arid zone.

### **6. Explored interface processes and their characteristics of MODS coupling relation**

Processes between systems and system interfaces display MODS coupling relations in arid zone. The distribution features, variation characteristics, interaction modes and cross relations of material, energy and information on the system interfaces directly restrict the structure and function of MODS. In the soil development and land covering, the irrigation of water integrant in SPAC and hydrothermal relations are major research subjects for spatio-temporal features and process simulation of MODS. The features of mountain-oasis system interface, ecological processes of transition belt of oasis-desert and interface processes of MODS all cannot be separated from their relied mediums as water, soil, and atmosphere. Among them, water is the most active factor in this MODS complex, and the major medium for material circulation, energy transform, and information transmission in natural environment. All in all, to study system coupling and its interface processes to comprehensively regulate functions of ecosystem is theoretically valuable.

Arid zone in western China has a vast land. And the air motion in this region is the major mode and pathway for material, energy, and information exchanges in MODS subsystems. Accompanied with air motion, water integrant, energy form will also change in response, and further establish an adaptive mechanism in MODS directly. With so many interfaces of MODS, in order to maintain the stability, protect ecological emergency, and promote system productivity, we need to regulate MODS according to objective rules and the demand from social development.

Because most interface processes are ecological significant, so, applying ecological feedback mechanisms, and exploring regulation modes and methods in special conditions of soil development and land covering, are pivots for the research in MODS coupling relations. Based on this, MODS concept modeling holds its solid entity. And

derivative MODS coupling modeling, desert-oasis relations modeling and MODS development mode further disclose the function and significance of MODS coupling relations.

### **Research level and innovation**

This research achieved innovative progresses in the explorations of theories, methods, practices, features, rules, and modes of MODS coupling. Within the research, by applying methods and means derivative from the combination of geographic information system and landscape ecology, the spatio-temporal features of mountain-basin system in arid zone were studied; MODS interface processes and kinetic mechanisms were elaborated based on hydrological processes; the features to describe oasis stability were discussed in the aspects of entropy variation in dissipative structural system and ecological fragility; the functionality of information transmission in the maintenance for the regular operation of ecosystem were emphasized; the evolution rules and development tendency of MODS were analyzed; the reconstruction and recovery modes for degraded ecosystem were established; the DTM modeling of Hetian oasis system and concept modeling for spatio-temporal coupling of ecosystem in arid zone were pressingly established, and the coupling relations of important elements related to landscape frame and their quantity features were analyzed; and finally, the ecological construction policies were put forward and focused on oasis landscape construction.

This research was developed in arid zone of western China where the ecological environment is fragile. So, the exploration of the evolution mechanisms and regulation measures of this ecological environment was not only the predetermined objective, but also the start point of the project. The research started with extant research results and experiences in China, and employed advanced technologies and implementation methods from overseas. The innovative aspects of this research were located at:

#### **1. Establishment of MODS concepts, theories and methods, and expansion of geographic information science, and landscape ecology**

In the biggest mountain-basin system in arid zone of

western China-Tarim Basin and its surrounding mountain areas, by utilization of satellite sensing technology and information processing, we studied spatio-temporal coupling relations of “Kunlun mountain-Hetian oasis-Taklimakan desert” system and “Tianshan mountain—Fukan oasis—Gurbantunggut desert” system, elaborated the features of spatial structure, spatial processes and their corresponding functions of MODS, explained spatial features and relations in the mountain-basin system of the arid zone in western China, disclosed material circulation, energy transform, and information transmission processes in those three (MOD) partnerships, and finally established theoretical frame for the research in ecosystem coupling.

## **2. Exploring interface processes and kinetic mechanisms, as well as putting forward the evolution process of western arid ecological environment system by tracing the formation, transform, consumption of water resource**

In the aspect of hydrology, we displayed MODS coupling features including spatial dissipation modes of material flux, energy flux and information flux; in the aspect of landscape ecology, we put forward ecosystem construction plan that focused on water pathway construction, vegetation landscape construction, and oasis landscape construction; in the aspect of water-salt coupling, we defined balance point between natural oasis and artificial oasis, and the concept of balance point provide a research platform to describe the spatio-temporal variations between artificial oasis and natural oasis in the same coupling system, and their supporting mechanisms.

## **3. Stability analysis of oasis system in the aspects of dissipation structural system entropy variation and ecological fragility**

By utilization of dissipation structural system theories, we disclosed the features and rules of energy transform of MODS in arid zone, elaborated the characteristics and rules of information transmission between water, soil and atmosphere of MODS in arid zone, and disclosed the relations between energy transform and system stability. We further analyzed inducing factors for the fragility of ecosystem in arid zone and elaborated the relations between human development activities and

ecological fragility. We analyzed ecological landscape of MODS by utilizing geographic remote sensing technology and landscape ecological methods, studied the quantity features and coupling relations of related essential elements of landscape frame, and put forward ecological construction methods.

## **Direction significance and research perspectives**

The study in MODS coupling relations pioneered new research topic in ecological environmental system in arid zone, provided new train of thought and methods in the exploration of evolution rules of ecological environmental system, and provided significant theoretical evidence to ecological environment regulation.

This research project made a series of innovative explorations according to the major objective to solve important issues in national ecological environmental system. We comprehensively studied different coupling relations within MODS and between its subsystems in arid zone from history evolution of landscape frame to the administration of arid desert environment, and from the protection and maintenance of natural oasis to the stability and development of artificial oasis. We also discussed formation mechanism of arid ecological environment and its evolution tendency to support ecological construction and environmental development in western China.

1. Research in MODS coupling relations: we emphasized on “three fluxes” and interface processes. And their related theories and rules directly led the macro distribution and human regulation in the processes of ecological construction. Our study integratively grasped characteristics and rules in the material circulation, energy transform and information transmission of MODS, and disclosed intrinsic system features in different levels from macro-scale ecological landscape to micro-scale water-salt coupling relations. Furthermore, our research achievements can be used to strongly support the integrative distribution of ecological environmental systems.

2. Research in water-salt balance point: this will directly lead the practices in the continuous development process of oasis system. The research in the water-salt balance point of natural oasis and artificial oasis system

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provide important theories and feasible plans for the maintenance of the stability of oasis system. And their potentials were effectively shown up in the practice in Weigan River.

3. Utilization of feedback mechanisms of ecology: we explored regulation modes of MODS in the specific soil development and land covering; and these regulation modes become the research pivots for coupling relations. MODS coupling modeling and MODS development modes hold important theoretical value and practical significance.

4. The theories and methods on MODS coupling relations, especially the simulation and quantity analysis on relations between subsystems and essential elements, need to be further intensively studied.

### Achievements in the Project - "The Adsorption of Rare Earth Metal Ions and Ligands on Steel, Aluminum and its Synergistic Mechanism"

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## 1. Background

Corrosion is a fundamental process that plays an important role in economics and safety, particularly for metals and alloys. Nowadays, corrosion problems have received a considerable amount of attentions. The annual direct cost of metallic corrosion ranges from 2% to 4% of national GDP in industrialized countries, and this cost sounds escalating in the future. Therefore, the research in metallic corrosion & protection is very important. They are not only technical problems, but also the problems of resource protection, energy saving, material saving, environmental protection and so on. Researchers in this field

endeavor to avoid all kinds of corrosions. The main strategy to prevent electro chemical corrosion is metal isolation from corrosive agents in the most effective possible manner, including anodic protection, cathodic protection, heat treatment, chemical passivation, conversion coating, surface treatment, electroplating, surface oxidation, inhibitor, and so on.

Inhibitor is the chemical agent that can drastically reduce corrosion rate of metal in corrosive medium, and the concentration of inhibitor is always very low (0.01 ~ 1000 mg/L). Among the above different methods available, the use of inhibitors is usually the most appropriate way to protect metals because of high efficiency, low price, and easy production. The inhibitor science is a new cross-disciplinary subject, namely, it studies the inhibitive effect and mechanism of the inhibitors for metals in different corrosive mediums. With the fast pace of oil chemical engineering and chemical cleaning, the development of inhibitor science was promoted greatly especially in the 1960s. The investigation of new non-toxic and green corrosion inhibitors is more strategic than in the recent past. In the 21<sup>st</sup> Century, the research in the field of "green" corrosion inhibitors has been addressed toward the goal of using cheap, effective molecules with low or "zero" environmental impact. In order to achieve the above objective, the basic theory of inhibitor is very important especially in the study of the inhibitive mechanism.

Synergism is a combined action of compounds greater in total effect than the summation of the individual effects ( $1 + 1 > 2$ ). Synergism of corrosion inhibitors is either due to the interaction between components of the inhibitor composition or due to interaction between the inhibitor and one of the ions present in the aqueous solution. Synergistic inhibition is an effective means to improve the inhibitive force of inhibitor, to decrease the amount of inhibitor usage, to diversify the application of inhibitor in acidic medium. Synergism plays an important role in not only theoretical research of corrosion inhibitors but also practical work.

Steel and aluminum have been found in wide applications in a broad spectrum of industries because of their low cost, high production and easy availability. China is rich in rare earth salts. Rare earth (RE) ions have low or