中国北方旱区农业研究

THE STUDY ON DRYLAND AGRICULTURE IN NORTH CHINA

信乃诠等 主编

中国农业出版社

中国北方旱区农业研究

THE STUDY ON DRYLAND AGRICULTURE IN NORTH CHINA

信乃诠等　主编

中国农业出版社

图书在版编目（CIP）数据

中国北方旱区农业研究/信乃诠等主编．—北京：中国农业出版社，2002.8
ISBN 7-109-07795-0

Ⅰ．中…　Ⅱ．信…　Ⅲ．干旱区－农业－研究－中国　Ⅳ．F327

中国版本图书馆 CIP 数据核字（2002）第 044857 号

中国农业出版社出版
（北京市朝阳区农展馆北路 2 号）
（邮政编码 100026）
出版人：傅玉祥
责任编辑　洪兆敏

中国农业出版社印刷厂印刷　　新华书店北京发行所发行
2002 年 9 月第 1 版　　2002 年 9 月北京第 1 次印刷

开本：787mm×1092mm 1/16　　印张：38.5
字数：1010 千字　　印数：1～800 册
定价：80.00 元
（凡本版图书出现印刷、装订错误，请向出版社发行部调换）

主　　编　信乃诠　张燕卿　王立祥

撰稿人员（按姓氏笔画排序）：

于沪宁　文宏达　王小彬　王立祥
王龙昌　王砚田　巨　辉　刘正辉
刘作新　同延安　孙占祥　吴东兵
张立峰　张燕卿　李　军　李立科
杜尧东　汪德水　罗其友　苗果园
郑大玮　郑家明　信乃诠　赵聚宝
贾志宽　陶　陶　高世铭　尉庆丰
曹广才　程延年　蔡典雄　樊廷录

审稿人员（按姓氏笔画排序）：

张燕卿　汪德水　罗其友
信乃诠　陶毓汾　蔡典雄

序

旱地农业，国外叫雨养农业（Dryland Agriculture）或雨育农业（Dryland Farming），简称旱农，是指干旱、半干旱和半湿润偏旱地区，主要利用自然降水、通过建立合理的旱地农业结构和采取一系列旱地农业技术措施，不断提高地力和自然降水的有效利用率，实现农业高产稳产和可持续发展的农业。

世界旱地农业的类型

干旱半干旱地区遍及世界各大洲，涉及50多个国家和地区，约占全球陆地（南极洲除外）面积的34.9%，共计5 470×10^4km^2。其中干旱地区3 140×10^4km^2，半干旱地区（包括大部分半湿润偏旱地区）1 430×10^4km^2，分别占全球陆地面积的24.0%和10.9%，其主要类型如下：

（一）热带季节干旱型　属热带沙漠气候，这类地区气候的主要特征是炎热、干燥。气温相当高，气温日较差特别大，昼热夜凉。降水常年不足100～200mm，且变率很大，有时甚至连续多年无雨，一年的降水往往集中在几次暴雨中。旱季经常延长到半年以上，农作物生长季节一般仅有12～24周。大致分布于南北回归线至南北纬30°之间的大陆内部或西岸。一般多进行游牧。

（二）热带半干旱类型　属热带草原气候，全年温度平稳，无明显低温，气候特征是干季、雨季交替明显，雨季草木旺盛，干季草原呈一片枯黄景色。年降水量500～750mm以上。这类地区多分布在热带干旱气候区的边缘，大致在南北纬10°至南北回归线之间。

（三）亚热带半干旱类型　属地中海气候，主要位于南北纬30°～40°之间的欧、美大陆的西岸，澳大利亚的东南部及非洲大陆的西南部。夏季高温干旱，冬季暖湿多雨。其农业生产特点主要是依靠冬季降水。澳大利亚南部生长季节较长，优于北非和西亚。

（四）中纬度干旱半干旱类型　属温带大陆性气候。主要分布在亚欧大陆和北美大陆的内陆地区，以及南北纬40°～60°的北美、南美东岸。干旱少雨，冬季严寒，夏季炎热。半干旱地带雨热同季，有利于农业生产。

就耕地面积而言，目前世界上耕地面积约$14\times10^8hm^2$，其中有灌溉条件的占15.8%左右，其余都是依靠自然降水从事农业生产，即所谓雨养农业。其中约有$6\times10^8hm^2$（占世界耕地面积42.9%）位于干旱半干旱地区，降水量均低于500mm，蒸发量大于降水量。然而，这类地区却生产着人类需要的大部分谷物。

基于这种情况，在干旱半干旱地区合理利用自然资源、保持水土、改善生态环境、发展旱地农业越来越引起有关国家和国际组织的重视，并总结推广发展旱地农业生产的实践经验、基本理论和先进适用技术。

历史悠久的旱地农业

世界旱地农业的产生和发展，是广大劳动人民几千年来和不利自然条件做斗争的结晶。世界农业发源地的两个中心——两河流域（幼发拉底和底格里斯河）和尼罗河下游，都受地中海气候的影响，西欧受大西洋暖流的影响，气候温和，雨量丰富，得天独厚，旱涝保收。惟有亚洲南部及中近东地区，干旱少雨，在公元前7 000年就有野生小麦、大麦和豌豆、扁豆、鹰咀豆种植；在埃及、苏丹等地有珍珠粟、高粱等种植。在印度次大陆，可能是在西巴基斯坦和印度河流域，发现有小麦、大豆、豌豆、小扁豆和亚麻。在美洲新石器时代，即公元前7 000—前6 000年间，印第安人驯化当地的动植物；在墨西哥南部气候干燥，气温较高，雨季集中于夏季两个月的特互坎河谷遗址中，就有玉米、南瓜、海岛棉种植。到了公元前2 500—前2 000年间，玉米、南瓜、菜豆等向墨西哥北部和现在的美国传播，其旱作技术已达到相当水平。

中国地处东亚季风区，旱涝频繁，黄河流域受大陆性气候的影响，更是“春多风旱”、“春雨难期”，春旱对农业的威胁极大。在这种不利的自然条件下从事农业生产，迫使人们采取各种措施以趋利避害。因此，在几千年的生产斗争中，形成了农业抗逆特点，使中国成为世界上旱地农业发展最悠久的国家之一。

中国传统的旱地农业，是沿着劳动集约这条途径逐步发展起来的，正如古人所说：“欲尽地力，至劳也”（《吕氏春秋·求人篇》）。中国旱地农业的经验原理，已由公元6世纪以前的《齐民要术》加以定型化。而这一原理与现代旱地农业的科学原理有近似之处，但在时间上约早2 000年。中国传统的旱地农业有悠久的历史渊源和独特的旱地农业技术表现：精耕细作，抗旱保墒；旱作地区的丰产技术，即垄作法、代田法、区田法等；用地养地相结合；争

夺天时地利；选种耐旱作物和品种；农林牧结合，注意生态平衡等。

从以上可以看出，中国世代相传的旱地农业传统，是以耕、耙、耱为中心，经验十分丰富。中国旱地农业不仅历史悠久，而且成就辉煌，同时在世界上也有很大影响。文艺复兴以来，世界上不少著名科学家都很重视中国早期有关旱地农业的记载。18世纪瑞典生物学家林肯，19世纪英国生物学家达尔文、德国农业化学家李比希、俄国化学家门捷列夫，都把中国古代农业科学成就作为他们建立自己学说的依据和例证。伟大的生物学家达尔文在他的《物种起源》的第一章就赞扬中国古代农学著作中清楚地阐明了物种选择原理，并引证中国的《齐民要术》、《本草纲目》等主要农学和药学典籍作为创建他的进化论学说的历史依据之一。农业化学学派创始人李比希也曾利用中国旱农的精耕细作、改良土壤、施用农家肥料和种植绿肥养地、以肥调水的成果，作为他探讨土壤肥力理论的重要依据。

对于中国传统的旱地农业，国外非常羡慕，并给予很高的评价。美国著名农学家、诺贝尔奖金获得者诺曼·布劳格说："这是世界已知的最惊人的成果之一"。R·布洛包姆也说："中国农业给其他地区农民有效地利用有机质提供了很好的经验。"

中国以精耕细作、抗旱保墒、用养结合著称的传统旱地农业，在几千年的历史上，繁衍养育了中华民族的炎黄子孙，也是中华民族世代相传的法宝。在向农业现代化进军的今天，既要学习外国的先进经验，也要继承和发扬我们祖先遗留下来的宝贵遗产，加速实现农业现代化。

正在传播的旱地农业

为了发展干旱半干旱地区的农业生产，早在联合国教科文组织成立不久的1951年就制定了大型的干旱地区研究计划，围绕着水分这个中心，对于旱半干旱地区进行了广泛的研究。进入20世纪70年代以来，国际农业磋商小组相继在叙利亚成立了国际干旱农业研究中心，在印度成立了国际半干旱热带作物研究所，在尼日利亚成立国际干旱热带作物研究所，分工协作，开展了全球干旱半干旱地区农业研究。与此同时，世界上有40个国家在干旱半干旱地区建立有关科研机构，从理论和实践上开展旱地农业研究，取得重要进展和成果，并在生产上广泛应用，取得巨大的成就。

麦类、粟类、高粱，耐旱的豆类和油料作物，以及马铃薯等，是需水量少、适于旱地的作物，种植面积不断扩大，其丰产性与耐旱性均有明显提高。如国际半干旱热带作物研究所选育的杂交高粱，20世纪70年代初在印度种植

面积170万hm^2，80年代初发展到500万hm^2。选育的谷子，具有丰产、抗病、适应性广等特点，百万公顷的平均产量从70年代初到80年代初每公顷增长45%。

在选种耐旱作物的同时，培育新的抗旱品种越来越受到重视。美国得克萨斯州选育的矮秆杂交高粱德卡普43，株高仅1.5m，穗大、丰产，能有效利用养分与水分，便于机械作业。内布拉斯加州选育的小麦抗旱品种有斯考特66（Scout）、科迪（Cody）、布克斯金（Bucksin）和Slouxland等。进入80年代以来，国际研究中心和一些国家的研究机构，采用现代生物技术，培育抗旱、抗病转基因新品种，获得了很大成功。

推行以保土保水为中心的保护性耕作技术发展很快。美国、加拿大、澳大利亚、俄罗斯等国推广包括浅耕灭茬、留茬深松、施用除草剂等项少耕免耕耕作制成效显著。美国在科罗拉多州阿克伦（Akron）采用免耕与少耕体制，耕作次数由7～10次减至1～3次，休闲地的土壤蓄水量从102mm（占降水量的19%）增加了55mm，达到占降水量的33%，使小麦产量成倍增加。目前，在美国中西部地区普遍推广少耕、免耕法，使昔日"黑风暴"的发源地成为今日的粮食商品生产基地，小麦产量占美国小麦总产量的63.7%。

覆盖栽培耕作能增加土壤蓄水保墒保肥性能，提高地温，保持水土，减少地表流失，防风蚀等危害，为作物生长创造一个良好的生态环境。这项技术发展很快，美国中西部地区少耕免耕普遍与覆盖栽培结合，一般是秸秆还田，留高茬覆盖，防旱增产效果显著。中国在半干旱地区，紧密围绕农田的蓄水、保水、供水和提高作物水分利用效率问题，大力推广秸秆覆盖、地膜覆盖技术，取得明显的增产效果。据多点测定，农作物产量一般增加20%～50%，有的可成倍增长，并改善品质。

采用多种形式的轮作制，具有保水保肥、用地养地的功效。美国中西部大平原推行三年两熟制，如一年小麦—休闲，第二年高粱，第三年休闲。这种轮作方式能有效地利用水分和恢复地力。目前这种轮作方式约占耕地面积的40%左右。据得克萨斯州测定，休闲轮作制小麦产量，80%年份高于每公顷670kg，连作仅有50%年份高于670kg。澳大利亚旱区采用牧草谷类作物轮作制，即一年苜蓿（1～2年）—小麦或大麦；降水偏多地区是三叶草（2～3年）—小麦或大麦。两种轮作中可根据情况加入完全休闲，其谷类作物增产显著。据有关资料，1952—1981年，小麦平均增产86kg/hm^2；1972—1981年的10年和1952—1961年的10年相比，单产增加8%，总产增加131%。近年来平均单产突破了300kg/hm^2水平。

集水农业，亦称径流农业或微型集水型农业受到重视，发展迅速，作用

显著。印度是多雨国家，但因雨季、旱季分明，一些地区湿润月份只有4～4.5个月，所以旱地农业占有重要地位。20世纪70年代以来，重视把造成水土流失的径流收集起来，用于农业生产，起到了很好作用。以色列、澳大利亚、墨西哥等国发展很快，建立了一批径流农场。近年来，中国甘肃省提出“集水农业”命题，实施“主动抗旱”战略，在总结传统经验和消化、吸收国外经验的基础上，建立有中国特色的集水高效农业的道路。

随着现代科学技术的发展，物理化学蓄水保墒新技术取得一定进展。例如抑制土壤蒸发的化学覆盖物、抑制植物蒸腾剂和土壤结构改良剂等，也开始得到应用。

面向新世纪的旱地农业

近年来，随着世界人口的急剧增加，耕地减少，水资源短缺，环境恶化，食物生产面临新的挑战，尤其是80年代以来的持续干旱，席卷主要产粮国，世界谷物总产量徘徊在18～20亿t，谷物的贸易量1.5亿t左右，谷物库存量下降到战后的最低点，仅为消费量的16%左右，低于粮食安全（17%～18%）所需要的水平。

这种情况引起了各国政府和国际组织的高度重视。1988年在美国得克萨斯州召开有47个国家和美国25个州代表参加的国际旱地农业会议，重点讨论旱地农业过去的进步和未来的挑战。接着又在前苏联、澳大利亚、泰国等召开旱地农业研讨会，广泛交流旱地农业技术与经验，以迎接世界新的挑战。

概括起来，推出以下重要举措：1）各国政府都把旱地农业研究与开发放在重要的战略地位。据最新统计资料，目前世界上已有40多个国家建立有关旱地农业研究机构近289个，其中分布在非洲有43个，亚洲69个，澳洲45个，欧洲36个，北美洲73个，南美洲23个。国际农业研究磋商小组在叙利亚、印度、尼日利亚建立旱农研究中心（所）。美国西部大平原的旱农研究目标明确，相对稳定，实行科研、教学、推广三结合，既面向生产，又重视基础性研究，有较雄厚的科技储备。俄罗斯、澳大利亚的旱农研究机构，面向生产实际，为旱农生产发展提供强有力的技术支撑；2）一些国家旱农研究机构组织多专业、多学科的结合，开展综合性研究。如叙利亚的国际旱农研究中心，设有谷物作物、食用豆类作物、牧草饲料和牲畜等系，均由遗传、育种、生理、生态、病理、昆虫、农经等专业人员组成，重点开展遗传资源评价与利用等研究，取得了不少科研成果，既解决了生产问题，又发展了学科。澳大利亚、印度等旱农研究机构也都是针对生产上的重大科技问题，开展多

学科的综合性研究；3）一些国家和国际旱农研究机构的研究与开发取得了一批重要科技成果。美国研究推广一套旱农增产技术体系，如选用耐旱作物和抗旱品种、集水节灌残茬覆盖、少耕免耕、粮草轮作（休闲）等。澳大利亚推广牧草谷物作物轮作制。国际研究中心所选育的高粱、谷糜、豆类耐旱新品种和农牧结合等，在旱地农业增产中发挥了重要作用；4）各国政府旱地农业研究与开发都在面向21世纪开展工作。随着淡水资源短缺，土地退化沙化，非灌溉面积进一步扩大，旱地农业将成为世界越来越突出的问题。国际干旱研究机构制定21世纪20年代发展规划，调整方向任务，加强基础性研究。美国提出近百项旱地农业研究课题，其中超前课题占40%左右。所有这些，必将对21世纪旱地农业的可持续发展做出新的贡献。

独具特色的旱地农业

中国是一个干旱缺水的国家。新中国成立后，特别是改革开放以来，中共中央、国务院高度重视旱地农业问题。1983年经国务院批准，农林部在陕西延安召开了“北方旱地农业工作会议”，重点是解决北方旱区粮食问题的发展战略。同时，将旱地农业研究与开发推向了一个新阶段。1990年农业部在山西省召开了“北方机械化旱作农业工作会议”，提出了北方干旱半干旱地农业机械化发展的重点任务。1995年，国务院在山西召开了以旱作节水为重点的“农田基本建设会议”，编制了《全国节水旱作农业发展规划》，并在国家计委的支持下，启动了“旱作农业示范建设工程”。1997年，为贯彻江泽民总书记等党和国家领导人关于“再造山川秀美的西北”的指示精神，国务院召开了“全国治理水土流失建设生态农业现场经验交流会”。随后，又于1998年通过了《全国生态环境建设规划》，并将发展旱作农业作为重要内容之一列入规划建设议程。所有这些，极大地推动了旱作农业的研究与开发。1984年中国广大科技工作者把传统的旱地农业技术与现代科学技术相结合，积极探索有中国特色的旱地农业理论与实践。在“六五”期间，北方旱地农业战略研究，首次列入农业部重点科技计划，由中国农业科学院组织9省、区农业科学院和5所高等农业院校参加的科研协作，完成了“北方旱地农业类型分区及其评价研究”。在此基础上，国家把北方旱地农业区域治理与综合发展研究列入“七五”、“八五”、“九五”重点科技攻关计划，由中国农业科学院组织了跨部门、跨地区和多学科的科技力量，团结协作，联合攻关，取得了一批具有创新性的重大科技成果，并在各类型区广泛推广应用，经济效益和社会效益巨大，生态效益明显，为推动北方旱区农业和农村经济发展做出了重要贡献。

信乃诠研究员等继组织撰写《中国北方旱区农业》之后，以15年国家科技攻关研究成果为基础，主持长期致力于北方旱区科技攻关的专家、教授，撰写出《中国北方旱区农业研究》一书，具有重要的实用价值和学术意义，为中国北方旱区农业可持续发展提供了重要依据，也极大地丰富了中国旱地农业科学。

我相信这本著作的出版，一定会受到学术界和广大农业系统的领导、科技人员和农业工作者的欢迎，并将为推动有中国特色的旱地农业的学科建设、农业和农村经济持续快速健康发展，发挥其更大的作用。

卢良恕

2002年3月

PREFACE

Dryland Agriculture, or Rainfed Agriculture, or Rainfed Farming, or Dryland Farming, is defined as the stable and high yield sustainable agriculture by rationally established farming structure and a series of technical measures good for increasing soil fertility and rainwater use efficiency specially for dryland conditions mainly depending on the natural precipitation including arid, semiarid and subhumid to arid areas.

The Types of Dryland Agriculture in the World

The arid and semiarid areas are widespread on every continent in the world, covering more than 50 countries and districts, occupying about 34.9% of global land area (except the Antarctic), totaling 54.7 million km^2. Among which, the arid area is 31.4 million km^2, and the semiarid (plus most of the subhumid to arid) is 14.3 million km^2, or 24.0% and 10.9%, respectively, of global land area. The main types are as follows:

(1) The tropical arid type: It is the tropical desert climate with the characteristic of hot and dry. The temperature is relatively high with big amplitude between day and night. The diurnal temperature is very high but the nocturnal is very low. The annual precipitation is less than 100～200 mm with great fluctuation. Sometimes, no rain falls for many years. The annual precipitation is often concentrated in a few storms. The dry season is often longer than half a year. The crop-growing season is only 12～24 weeks long. It is located mainly in hinterland or west bank areas between the Tropic of Cancer to 30°north latitude and the Tropic of Capricorn to 30°south latitude. Most of the people live on nomad.

(2) The tropical semiarid type: It is the tropical grassland climate with relatively stable temperature without extremely cold weather. It is featured by obvious alternation of dry and wet seasons. In rainy season, plants grow vigorously, whereas in dry season the landscape turns yellow. The annual precipitation is around 500～750 mm or more. It is located mainly along the edges of the tropical desert climate areas, approximately between the Tropic of Cancer to 10°north latitude and the Tropic of Capricorn to 10°south latitude.

(3) The subtropical semiarid type: It belongs to the Mediterranean climate, mainly locating in west banks of European and American continents between the 30°～40°both north and south latitudes, southeast Australia and southwest Africa. There are hot dry summer and warm rainy winter. The farming largely relies on rainfall in winter. The growing season

in southern Australia is longer than those in northern Africa and western Asia.

(4) The mid-latitude semiarid type: It belongs to the continental climate, mainly distributed in the hinterlands of Asia-Europe continent and American continent and the east banks of the North America and South America between the $40° \sim 60°$ both north and south latitudes. It is dry and lack of rainfall, with cold winter and hot summer. The semiarid area has synchronized rainy and warm season that is good for farming production.

As for the acreage of arable land, the total area in the world today is 1.4 billion hm^2. Among which, 15.8% has irrigation condition. The rest is depending on natural precipitation. So, it names as rainfed farming. Among which, 0.6 billion hm^2 (or 42.9% of global farm land) befalls into the range of arid and semiarid areas with annual precipitation less than 500 mm, while the evaporation more than the precipitation. Nevertheless, these areas are producing most of the food for people.

Based on the situation mentioned above, the reasonable utilization of natural resources, soil protection, eco-environment improvement and development of dryland farming are being paid more and more attention by relevant countries and international organizations. They summarize and extend practices, basic theories and advanced technologies on dryland farming production development.

The Dryland Farming with Long History

The appearance and development of the worldwide dryland farming is the outcome of the struggle against adverse natural conditions for thousand years by peoples. The two origins of the world agriculture, namely the twin-river (Euphrates and Tigris) valleys and lower reach of Nile, both affected by Mediterranean climate. The West Europe is influenced by the Atlantic warm ocean-current. The weather in these two parts is warm with rich rainfall good for farming with little impact by drought or flood. Only the South Asia and Middle and Near East are dry and short of rains. As early as 7 000 years ago, the wild wheat, barley, pea, lentil and chickpea were planted. In Egypt and Sudan the pearl millet and sorghum were grown. It is found that in India Subcontinent, maybe in the western Pakistan or the Indus River valley, the wheat, soybean, pea, lentil and flax were planted. During the American Neolithic Age, or 7 000-6 000 B.C., the Indians has acclimatized local plants and animals. In the Teotihuacan relics in Mexico, the corn, pumpkin and sea-island cotton were planted. The weather there was dry and hot, the rainfall befell into 2 months in summer. Until 2 500-2 000 B.C., corn, pumpkin and beans planting was expanded to north Mexico and to the places where belong to the United States territory today. The dryland farming technology had been developed to a relatively high level.

China locates in the East Asia monsoon region with frequent drought and flood. The Yellow River valley affected by continental climate is with "windy and dry spring" and "rare vernal drizzle" . Spring drought spells threaten agricultural activities. Under such adverse conditions, farmers were enforced to assume various measures for chasing benefits and escaping losses. Therefore, with thousands years practices, Chinese dryland agriculture has become one of the longest lasting one full of resistance against adverse conditions.

The traditional Chinese dryland farming was developed along the route of labor intensity. As said by ancient scholar in the Labor Employment Chapter in the ancient works of Luishi Encyclopedia: "in order to exploit the fertility to a full extent, use intensive labors." The fundamentals of Chinese dryland farming have been figured out by another ancient book: The Important Know-how for Farmers in Qi Country. The ancient theory is very similar to the modern one. The difference is that it appeared 2 000 years ago. The historical and unique traditional Chinese dryland farming technology exists in intensive tillage and cultivation, resisting drought by preserving soil moisture. Ridge plowing method, furrow-seeding method (or Daitian method: ridge-furrow plowing and seeding in furrows for keeping soil moisture, to level the soil on ridges when hoeing and weeding, to exchange the positions of ridge and furrow next crop) and square-pit method (or Qutian method: dig a square pit, putting manure on the bottom, then cover with soil and watering before seeding) were applied. The soil fertility exploitation was with betterment. Taking measures timely in accordance with weather and soil conditions. Choosing drought tolerant crops and varieties. Combining crop cultivation with animal husbandry and forestry. Keeping the balance of eco-environment.

From what above mentioned we see that the experienced Chinese traditional dryland farming was based on the plowing, raking and harrowing. The Chinese traditional dryland farming is with not only long history, but also fruitful achievements, having great contribution to the world agriculture. Since the Renaissance, there were numerous famous scientists paid great attention to Chinese early records on dryland farming. The Swedish biologist Mr. Linné in 18th century, the British biologist Mr. Darwin, the German agro-chemist Mr. Libig and the Russian chemist Mr. Mendelev in 19th century all took instances from ancient Chinese agricultural scientific achievements when establishing their own doctrines. The great biologist Mr. Darwin appraised the ancient Chinese agricultural works as clearly explained the rationale on species selection in his first chapter of The Origin of Species. He also cited the contents from ancient Chinese agricultural works The Important Know-how for Farmers in Qi Country and from the medical works Compendium of Materia Medica as one of the historical bases when he created his evolution doctrine. The agro-chemist Mr. Libig took the advantage of Chinese dryland farming achievements on intensive cropping, soil amelioration, applying farmyard manure and planting green manure for soil betterment, increasing water use efficiency by fertilization when he studied the theory on soil fertility.

The Chinese traditional dryland farming has got great reputation and appraisal worldwide. The famous American agronomist and Nobel Prize winner Mr. Norman Brog said that it is the most astonishing achievement known in the world. Mr. Blowbomb also said that Chinese agriculture has presented for farmers in the other countries a good experience on using organic matter efficiently.

With traditional Chinese dryland farming characterized by the intensive cropping, resisting drought and preserving soil moisture, and exploiting with keeping soil fertility has fed the Chinese people for thousands years. It is a treasure for this nation. When we speeding up to realize the agricultural modernization today, we have to learn from foreign advanced technology and from the precious heritage of our ancestors, too.

The Spreading of Dryland Agriculture

In order to develop agricultural production in arid and semiarid areas, as early as 1951 soon after the foundation of United Nations Education, Science and Culture Organization, the large-scale study program on dry areas was worked out. Widespread studies have been conducted on arid and semiarid regions focus on water issues. Since 1970s, the International Center for Agricultural Research in the Dry Areas in Syria, the International Crops Research Institute for the Semiarid Tropics in India and the International Institute for Tropical Agriculture in Nigeria were built up one by one by the Consultative Group on International Agricultural Research. They cooperated with each other on global agricultural research on arid and semiarid regions. Concurrently, there were 40 countries in the world established relevant scientific research institutions in arid and semiarid regions, in order to study dryland farming from theory and practice aspects. The important progress has been made and used on production. The achievement is great.

Small grain cereals, millets, sorghum, drought tolerant pulses and oil-bearing crops, and potato are crops requiring less water and suitable for dryland farming. Their seeding acreage is growing consistently. Both their yields and drought tolerance have been being improved obviously. For example, the hybrid sorghum bred by the International Crops Research Institute for the Semiarid Tropics was planted 1.7 million hm^2 in 1970s, then 50 million hm^2 in 1980s in India. The millet developed by this institute had features of high-yield, disease resistance and wide adaptation. Its yield per hectare increased by 45% in 1980s against 1970s on million hectares.

Correspondingly with the planting of drought tolerant crops, the drought resistant varieties breeding was being paid more and more attention. The dwarf hybrid sorghum Dekarp 43 developed in Taxes, US had the plant height of 1.5 m, big ears and high yield. It was able to use nutrients and water effectively and easy for mechanical operations. In Nebraska State, many drought resistant wheat varieties were developed such as Scout 66, Cody, Buckskin and Slouxland. From 1980s on, some international research centers and national research institutions have developed drought and diseases resistant trans-gene varieties with modern biological technology very successfully.

Conservation tillage aiming at preserving soil and moisture developed rapidly. Less till or no-till including shallow plowing with stubble elimination, subsoiling with crop residues and the application of herbicides had been extended in the USA, Canada, Australia and Russia with significant effects. As for the no-till in Akron, Colorado, US, the plowing frequencies reduced from 7~10 times to 1~3 times, the soil moisture retention on fallow field increased by 55 mm on the basis of 102 mm (19% of the precipitation), accounting for 33% of the precipitation. The yield of wheat was doubled. At present, in middle and west US, the less till or no-till is applied popularly. The origin of "Black Storm" in the past has become commercial grain production base today with 63.7% of total wheat output in USA.

Mulch cultivation enables to increase soil nutrient and moisture retention, enhance soil temperature, protect soil surface, reduce run-off and resist wind erosion. A better eco-environment condition will be created for crop growing. The middle and west US regions with less till or no-till usually assume mulch technology. The mulch with high stubble standing on the fields has good effect on drought resistance and yield increase. In the semiarid areas in China, the mulch by stubbles or plastic films was extended for the purpose of moisture collection, retention and supply for increasing water use efficiency, hence the yield increase. According to survey in many sites, crop yields normally increased by 20%~50% or even doubled, besides the quality improvement.

Many types of rotation systems have the function of nutrient and water retention, as well as exploiting with keeping fertility. The system of 2 crops in 3 years, such as wheat-fallow (1st year), sorghum (2nd year), and fallow (3rd year) was applied on the Great Plain in the middle and west US. This kind of rotation is able to utilize moisture and recover fertility efficiently. Nowadays, it covers 40% of the arable land. According to the test in Taxes state, there are 80% years saw the yield up to 670 kg/hm^2 from rotation system, whereas only 50% years saw the same yield from continuous cropping. Pasture-cereal rotation system is assumed in dryland in Australia, or alfalfa (for 1~2 years) - wheat or barley. In much rainy areas, the system of clover (2~3 years) - wheat or barley is applied. The complete fallow can be added into these two systems, resulting in significant increasing cereal yields. Based on the statistics, the average annual yield increase was 86 kg for the period of 1952-1981. Comparing with in the decade of 1952-1961, the yield increased by 8% and the output by 131% in the decade of 1972-1981. In recent years, the average yield broke through 4 500 kg/hm^2.

Water harvesting agriculture, or run-off agriculture, or micro-water collection agriculture, is emphasized and developed fast. It has obvious effect. India is a rainy country. But because the evident division of rainy season with dry season, the wet season has only 4~4.5 months. Therefore the dryland farming plays an important role. Since 1970s, the collection of run-off water for agricultural production, otherwise it may cause soil erosion, was highlighted and displayed good results. It is developed rapidly in Israel, Australia and Mexico, where a number of run-off farms were built up. In the recent years, Gansu Province of China encouraged water-harvesting agriculture for the "Active Drought Resistance" strategy. On the basis of summarizing traditional experiences and studying foreign experiences, a Chinese characterized high efficiency water harvesting agriculture is being established.

With the development of the modern scientific technology, the newly physico-chemical method for moisture retention has made some advancement, such as the initial application of chemical mulch materials restricting evaporation, transpiration inhibitors and soil structure conditioners.

The Dryland Agriculture Facing New Century

With the dramatic growing of world population in recent years, arable land decreasing, lack of water resources and degradation of environment, the food production is facing a new challenge. Especially the sustained drought spell since 1980s spreading in major grain production countries, the global cereal output is stagnating by 1.8～2 billion tons, with trading tonnage by 150 million tons. The storage of cereal dropped to the lowest point after the World War II, only at 16% of consumption. It is lower than the safe grain line of 17%～18% of consumption.

This situation has attracted highly attention by governments of countries and by international organizations. In 1988, the International Dryland Agriculture Conference was held in Taxes, USA. Representatives from 47 countries and 25 states in US participated this meeting. They discussed on emphasis about the progress on dryland farming made in the past and the challenge be faced in the future. Then seminars on dryland farming were held in pre-USSR, Australia and Thailand. The technology and experiences on dryland farming were exchanged in order to face the new challenge ahead for the whole world.

Generally speaking, the following countermeasures had been raised: 1) The governments of countries put the dryland agriculture research on an important strategic position. Based on the newest investigation, there are nearly 289 research institutions on dryland agriculture in more than 40 countries in the world today. Among which, 43 is in Africa, 69 in Asia, 45 in Oceanic, 36 in Europe, 73 in North America and 23 in South America. The Consultative Group on International Agricultural Research set up dryland farming research centers in Syria, India and Nigeria. The dryland farming research in West Plain of US had explicit objects, which was relatively stable. It combined the scientific research with education and extension. It was not only for production, but also emphasized fundamental studies. It had rich scientific reserves. The Russian and Australian research institutions on dryland farming studied for the production, as a strong scientific basis. 2) Some research institutions on dryland farming organized multidisciplinary studies. For example, the International Center for Agricultural Research in the Dry Areas in Syria had Departments of Cereals, of Edible Pulses, of Pasture and Fodder, and of Animal Husbandry. They were composed of by specialists on genetics, breeding, physiology, ecology, pathology, entomology and agro-economy. The highlighted study was on the evaluation and utilization of genetic resources. Many achievements had been obtained. It not only solved