

中国秸秆资源 综合利用技术

Comprehensive Utilization Technology of
Straw Resources in China

毕于运 寇建平 王道龙 等编著

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图书在版编目 (CIP) 数据

中国秸秆资源综合利用技术/毕于运, 寇建平, 王道龙等编著. —北京:
中国农业科学技术出版社, 2008. 9
ISBN 978 - 7 - 80233 - 614 - 8

I. 中… II. ①毕…②寇…③王… III. 秸秆 - 综合利用 - 中国 IV. S37

中国版本图书馆 CIP 数据核字 (2008) 第 070436 号

责任编辑 刘 建
责任校对 贾晓红

出版者 中国农业科学技术出版社
北京市中关村南大街 12 号 邮编: 100081
电 话 (010) 82106638 (编辑室) (010) 82109704 (发行部)
(010) 82109703 (读者服务部)
传 真 (010) 82109709
网 址 [http://www. castp. cn](http://www.castp.cn)
经 销 者 新华书店北京发行所
印 刷 者 北京科信印刷厂
开 本 889 mm × 1 194 mm 1/16
印 张 17.5
字 数 500 千字
版 次 2008 年 9 月第 1 版 2008 年 9 月第 1 次印刷
定 价 59.00 元

内容提要

本书共分十章，主要从秸秆肥料化利用、饲料化利用和新型能源化利用三个方面，详细论述了秸秆资源综合利用技术的原理、工艺流程、技术类型及相关应用实例，并根据各种技术在实践中的应用情况进行了综合效益分析。具体内容包括秸秆直接还田技术与土壤培肥、水田免耕秸秆覆盖还田栽培技术及其效用分析、秸秆生物反应堆技术及其效用分析、秸秆堆沤还田技术与土壤培肥、秸秆饲料加工处理与利用、农村户用沼气发展与秸秆沼气建设、秸秆固化炭化技术与应用、秸秆气化技术与秸秆气化集中供气、秸秆液化技术、秸秆发电技术与应用。

本书内容丰富，系统性、技术性、实用性较强，力求能为我国秸秆资源的集约、循环、充分、高效利用提供技术支撑和有益指导。本书适合于农业及生物质资源、可再生能源领域科研人员、管理人员及生产技术实践人员使用，亦可供高等院校相关专业师生参考。

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我国秸秆资源综合利用的系统构成及总体趋势 (代序)

秸秆资源上承种植业，下启养殖业，既是种植业和养殖业可持续发展的重要物质基础，又是构建农业循环经济系统种植业与养殖业之间的重要纽带，对我国现代农业的可持续发展起着决定性的影响和作用。

一、我国秸秆资源综合利用的现实构成

秸秆主要有五个方面的用途：一作燃料，二作饲料，三作肥料，四作工业原料，五作食用菌基料，简称“五料”。

2005年，我国秸秆总产量84 183万t，其中可收集利用秸秆量68 595万t，占81.48%；秸秆田间残留量15 588万t，占18.52%。2005年在我国可收集利用秸秆总量中，直接燃用量23 939万t，占34.90%；新能源开发利用量约470万t，占0.69%；饲用量17 658万t，占25.74%；工业加工利用量约4 600万t，占6.71%；食用菌栽培利用量约1 000万t，占1.46%；直接还田量约6 730万t，占9.81%；废弃和焚烧量14 198万t，占20.70%。

二、我国秸秆资源综合利用的系统构成

不同秸秆利用方式对农业循环经济系统的影响和作用有着明显的区别，从此角度出发，首先可把秸秆资源利用类型划分为两大类：一类是农业生产系统内部的秸秆资源循环利用；另一类是农业生产系统外部的秸秆资源利用。农业生产系统外部的秸秆资源利用，无论利用效率高低，都属于单线经济的范畴。根据秸秆资源利用与农民生活和农村经济的关系，又可将农业生产系统外部的秸秆资源利用划分为两类：一类是农村社会经济系统内部的秸秆资源利用；另一类是农村社会经济系统外部的秸秆资源利用。

1. 农业生产系统内部的秸秆资源循环利用

农业生产系统内部的秸秆资源循环利用包括秸秆肥用、秸秆饲用、秸秆沼气、秸秆食用菌栽培。

对于秸秆沼气，从其可产出沼气、满足农村清洁能源需求的角度来看，可将其归入农村社会经济系统内部秸秆资源利用的范畴；从其可生产优质高效有机肥还田的角度来看，又可归入农业生产系统内部秸秆资源循环利用的范畴。但从其物质转换比例来看，秸秆经过常温发酵，约有25%转换为沼气，75%转换为沼肥，尤其是从其可进一步延长秸秆产业链条、有效促进秸秆资源循环高效利用的作用来看，应主要将其视作农业生产系统内部的秸秆资源循环利用。

秸秆资源在农业生产系统内部的利用效果可大致归结为如下三个方面：首先，秸秆资源的系统内部应用把种植业子系统和养殖业子系统有机地联系在一起，成为构建“种植业-养殖业”循环经济系统的关键连接点。其次，秸秆资源的系统内部应用不仅是提高秸秆利用率的基本手段，更主要的是其可直接增加“种植业-养殖业”系统的物流和能流，使“种植业-养殖业”系统更加健康、稳固。第三，秸秆资源在系统内部应用过程中，通过各级转化，可为人类提供更多的农产品，大部分或部分营养物质最终又回归到农田，从而使农田与种植业、养殖业构成一个闭合的资源经济系统，有利于农田生态系统的良性循环。秸秆直接肥用自不必多言，饲用秸秆可



过腹还田，秸秆栽培食用菌可生成优质有机菌肥还田，尤其是“秸秆-沼气”、“秸秆-牲畜-粪便-沼气”和“秸秆-食用菌-菌糠-沼气”等秸秆循环利用模式，不仅可生产清洁能源，有效地替代秸秆资源的直接燃用，而且可生成优质有机肥还田。

2. 农村社会经济系统内部的秸秆资源利用

农村社会经济系统内部的秸秆资源利用主要是指与农民生活密切相关的秸秆能源化利用，包括秸秆直接燃用和秸秆气化、秸秆固化等农村新型能源开发利用。秸秆新能源开发利用，既直接利用了秸秆，又替代了秸秆的直接燃用，可使农村秸秆燃用消耗总量呈下降的趋势。秸秆新能源开发利用同时还可替代煤、电、“三气”等商品能源的使用。按照现实农村生活中秸秆直接燃用的热效率和秸秆新能源开发利用的热效率来折算，平均每吨用于新能源开发利用的秸秆可替代2~3t直接燃用的秸秆。秸秆新能源开发利用可促使秸秆资源系统外部利用量的减少，为秸秆资源的系统内部利用创造条件，但在现阶段也会导致秸秆剩余量的增加。

3. 农村社会经济系统外部的秸秆资源利用

农村社会经济系统外部的秸秆资源利用包括秸秆工业加工、秸秆发电和秸秆液化。

对于秸秆发电和秸秆液化，毫无疑问属于秸秆新能源的范畴，而且可通过秸秆交易为农民带来一定的收入，但从其生产目的来看，尤其是规模化秸秆发电，并不是为了解决农民一家一户的能源问题。秸秆发电，把一家一户的秸秆收集起来转换为电力，再供给农民，其生产成本和能源效率远不如秸秆沼气、秸秆气化、秸秆固化等新能源开发利用方式。因此，我们有理由把秸秆发电和秸秆液化划归农村社会经济系统外部秸秆资源利用的范畴。

农村社会经济系统外部的秸秆利用是我国秸秆产业化的主要发展途径。农村社会经济系统外部的秸秆利用对提高我国秸秆资源的综合利用率，有效地解决秸秆资源的废弃与焚烧问题，促进秸秆产业化发展有着十分重要的作用。但农村社会经济系统外部的秸秆资源利用，无论利用效率高，都使秸秆资源的物质和能量从农业循环经济系统中被汲走，即使注意对“草木灰”的收集利用，最终也只有少量的营养物质（以K、P为主）能够回归农田。如果农村社会经济系统外部的秸秆资源利用过量，将导致农业生态系统中各子系统（包括土壤肥力子系统、种植业子系统和养殖业子系统）的相互脱节，威胁到农业的循环发展。

三、我国秸秆资源综合利用存在的主要问题

目前，我国秸秆资源利用仍存在着综合利用不充分、利用结构不合理等方面的问题，具体表现在：一是秸秆综合利用率低。如果不考虑秸秆的直接燃用，目前我国秸秆的综合利用率还不到45%。二是秸秆废气和焚烧问题较为严重，并对交通运输、农业生产和城乡居民生活带来诸多不利影响。秸秆焚烧成为我国久治不愈的社会问题。三是农业生产系统内部的秸秆利用量低于系统外部的秸秆利用量。2005年，全国农业生产系统内部的秸秆利用量为25 389.00万t，比农业生产系统外部的秸秆利用量29 007.34万t低12.47%。在全国已利用秸秆中，农业生产系统内部利用量占46.67%，系统外部利用量占53.33%。四是农业生产系统外部的秸秆资源利用仍以效率最低的秸秆直接燃用为主，用于农村新能源开发利用的秸秆数量十分有限，“四化一电”（秸秆气化、秸秆固化、秸秆炭化、秸秆液化和秸秆发电）利用秸秆量不到500万t。五是农村社会经济系统外部的秸秆资源利用量不高，秸秆产业化发展仍十分薄弱，对提高我国秸秆资源综合利用率所起作用还十分不到位。2005年全国农村社会经济系统外部的秸秆资源利用量为5 051.70万t，占全国秸秆可收集利用总量的7.36%。

四、集约、循环、高效、充分利用秸秆资源

秸秆资源现实利用既不能任其向低效率的用途转移，也不能因其利用不当对农业和农村经济



可持续发展构成威胁,更不能任其被随意焚烧和废弃。为了早日建立“资源节约型”、“环境友好型”、“社会和谐型”的社会主义新农村,针对我国秸秆资源现实利用中所存在的诸多问题,必须以秸秆资源的集约、循环、高效、充分利用为总体取向,因地制宜、统筹规划,合理配置秸秆资源,优化秸秆利用结构,既要充分合理利用秸秆资源,又要避免重复建设和不必要的竞争,优先保证农业生产系统内部和农村社会经济系统内部的利用需求,兼顾农村社会经济系统外部的利用需求;依靠科技、创新机制,充分发挥科技进步在秸秆综合利用中的支撑作用,不断提高秸秆资源的利用率和利用效率,逐步减少秸秆的直接燃用消耗,从根本上解决秸秆废弃和焚烧的问题,保障农业和农村经济的可持续发展。

1. 以秸秆还田、秸秆养畜、秸秆栽培食用菌为主攻方向,集约、循环、高效利用秸秆资源,努力增加农业生产系统内部的秸秆利用

循环农业是我国农业和农村经济可持续发展的重要实现途径。从此要求出发,秸秆资源利用首要的是满足农业生产系统内部的需求。目前,我国秸秆资源的内部利用需求严重不足,土壤肥力子系统、种植业子系统、养殖业子系统相互间脱节,由此导致土壤板结化、农产品品质退化、水体富营养化等问题日益严重。从土壤培肥的要求出发,农业生产系统内部的秸秆利用量应占到秸秆可收集利用总量的50%以上。为此,要鼓励和扶持发展肥用、饲用和食用菌栽培等途径的秸秆资源化利用。大力发展秸秆还田,充分利用秸秆这一有机肥资源,增加土壤养分,培肥地力,促进农业增产增效,提高农产品质量和食品安全。重点推广秸秆还田配套机械和技术、秸秆快速腐熟还田和秸秆生物反应堆等技术。在具备免少耕条件的区域,积极发展秸秆保护性耕作,并针对农村劳动力大量外流的现实,重点推广秸秆覆盖免耕轻型栽培技术。鼓励建设秸秆有机肥生产厂。大力发展秸秆畜牧业,通过青贮、氨化、微贮、压块、揉搓丝化等处理方式,把秸秆转化为优质饲料,以秸秆“换肉、换奶”,保证畜产品供应和食品安全。积极发展以秸秆为基料的食用菌生产。大力发展沼气,延长秸秆产业链,协调农业生产系统内部的秸秆利用与秸秆新能源开发利用之间的关系,并生产更多的沼肥还田。

2. 加强农村秸秆新能源开发,集约、高效利用秸秆资源,充分满足农村社会经济系统内部的秸秆利用需求,不断减少秸秆的直接燃用消耗

我国秸秆新能源开发利用虽然处于起步阶段,但深受农民的欢迎,具有较强的公益性和社会影响力,已经成为各级政府建设社会主义新农村建设的有力“抓手”。因此,对于农村秸秆新能源开发理应给予积极的倡导和大力的扶持,结合新农村建设和乡村环境整治,大力发展秸秆气化、固化及炭化,使其不断向市场化、产业化的方向迈进,努力实现秸秆新能源对秸秆、薪柴直接燃用以及煤炭等化石能源的替代。

3. 合理安排农村社会经济系统外部的秸秆利用,建立以秸秆深度开发利用为核心的秸秆资源产业化体系,集约、高效利用秸秆资源,将秸秆资源优势转化为经济优势,带动区域经济发展,进而促进秸秆资源的充分利用

稳步推进以秸秆为原料的加工业发展:推广应用草浆清洁造纸技术,鼓励和扶持发展零排放秸秆造纸,切实解决草浆造纸的环境污染;大力发展以秸秆为原料的建材、包装材料、餐具等产品生产,替代木材,减轻植被和森林的压力;积极发展秸秆制品加工业。根据区域社会经济发展要求,在秸秆资源分布密度较高的地区,在优先保证农业生产系统内部和农村社会经济系统内部的秸秆利用需求的条件下,充分发挥秸秆发电在解决秸秆废弃问题上的积极作用,合理布局秸秆发电厂,大、中、小秸秆直燃发电、混燃发电、气化发电等多种秸秆发电方式相结合,发展绿色能源,有效地提高秸秆利用率和利用效率。对于规模化秸秆发电既要适量发展,更要合理布局,避免盲目建设,严禁一哄而上。各级主管部门,对秸秆发电尤其是大中型秸秆项目审批,一定要



慎重对待。否则，大规模的秸秆集中收集和掠夺式利用，势必对农业生产系统内部秸秆资源的循环利用构成威胁。与此同时，要针对秸秆生产分散，季节性强，易腐烂，收集和存贮成本大，占地多等问题，研究建立以企业为龙头，农户参与，县、乡镇政府监管，市场化推进的秸秆收集体系和物流体系，建立必要的秸秆贮存管理制度。重点鼓励发展秸秆打捆收贮，尤其是与农作物收割、贮运一体的机械化联合作业。

五、我国秸秆资源综合利用的总体趋势

我国秸秆资源综合利用的总体趋势具体体现在“四个增加”、“两个减少”、“一个替代”。“四个增加”：一是秸秆新能源开发利用量增加；二是秸秆饲用量增加；三是秸秆工业加工利用量增加；四是秸秆食用菌栽培利用量增加。“两个减少”：一是秸秆废弃和焚烧量减少，直至完全杜绝；二是秸秆直接燃用量减少。“一个替代”是指秸秆过腹还田、秸秆沼肥还田和秸秆过腹沼肥还田逐步替代秸秆直接还田。秸秆直接还田是最快捷、最能批量处理秸秆的方式。为了尽快解决秸秆废气和焚烧问题，近期内我国秸秆还田量必将大幅度增加。但从长远看，随着“替代”量的增加，我国秸秆直接还田量必将呈现出不断减少的趋势。

预计到2010年和2015年，全国秸秆直接还田量将分别达到1亿t和1.3亿t以上，年均新增秸秆还田量650万t左右；秸秆饲用量分别达到2.27亿t和2.77亿t，年均新增饲用秸秆1000万t，秸秆养畜量分别达到5.7亿只羊单位和7亿只羊单位；农村新能源（包括秸秆沼气、秸秆气化、秸秆固化、秸秆炭化等）开发利用秸秆量分别达到260万t以上和5000万t；秸秆发电利用量分别达到1000万t和3000万t；秸秆工业加工利用量分别达到6150万t和7800万t；食用菌栽培利用秸秆量分别达到1400万t和2160万t。与此同时，全国秸秆直接燃用量分别下降到1.85亿t和1.2亿t。

从秸秆利用的三大系统来看，由2005年到2010年和2015年，全国农业生产系统内部利用秸秆量将由25389万t分别增加到34206万t和43495万t，分别净增8817万t和18106万t，其占全国秸秆可收集利用量的比重将由37.01%分别提高到49.12%和61.07%；随着秸秆直接燃用量的大幅度减少，全国农村社会经济系统内部秸秆利用量将由23957万t分别下降到18635万t和16924万t，分别净减少5322万t和7033万t，其占全国秸秆可收集利用量的比重将由34.93%分别下降到26.76%和23.76%；农村社会经济系统外部秸秆利用量将由5052万t分别增加到7150万t和10800万t，分别净增2098万t和5748万t，其占全国秸秆可收集利用量的比重将由7.36%分别提高到10.27%和15.16%。

通过秸秆综合利用，到2010年全国秸秆剩余量下降到1亿t以下，到2015年基本解决全国的秸秆废弃和焚烧问题。在不计秸秆直接燃用的情况下，全国秸秆综合利用率将分别达到60%左右和80%以上。

作者

2008年8月

System Composition and General Trend of Straw Resources Comprehensive Utilization in China

(As A Preface)

Straw resource has a decisive effect on the sustainable development of modern agriculture in China. It is related to crop cultivation and livestock breeding, which is not only the material base of the sustainable development of crop cultivation and livestock breeding, but also an important links between them for building sustainable development of modern agriculture .

I Realistic composition of straw resources comprehensive utilization in China

The main uses of straw are as follows: for fuel, for feed, for fertilizer, for industrial raw material and for base material of edible fungi, which can be simply described as ‘five material’ .

In 2005, China’s total straw production is about 841.83 million tons, and the collectible and available amount is 685.95 million tons which accounts for 81.48% of the total straw production, and the residues in soil is about 155.88 million tons which accounts for the rest 18.52%. In the total quantity of collectible and available straw in 2005, the quantity of straw burning directly is 239.39 million tons and accounts for 34.9%, and the quantity of the development and utilization of straw resource for new energy is 4.7 million tons and accounts for 0.69%, and the quantity for feeding is 176.58 million tons and accounts for 25.74%, and the quantity for industrial processes and utilization is about 46 million tons and accounts for 6.71%, and the quantity for edible fungi cultivation is about 10 million tons and accounts for 1.46%, and the quantity of returning straw to soil directly is about 67.3 million tons and accounts for 9.81%. The rest 141.98 million tons are for burning and discarding which account for the rest 20.70%.

II System composition of straw resources comprehensive utilization in China

Different ways of straw utilization have significantly different influences on agricultural circular economy system. So, the utilization of straw resources can be divided into two types, one is the recycle utilization of straw resources inside the agricultural production system, and the other is the utilization of straw resources outside the agricultural production system. The utilization of straw resources outside the agricultural production system belongs to single-track economy, no matter the utilization efficiency. According to the relationship among utilization of straw, farmers’ life and rural economy, we can also divide the utilization of straw resources outside the agricultural production system into two kinds, namely, utilization of straw resources inside and outside the economic system in rural society.

1. Recycle utilization of straw resources inside the agricultural production system

Recycle utilization of straw resources inside the agricultural production system includes using straw for fertilizer, feed, biogas and edible fungi cultivation.

For straw biogas, from the perspective that it can produce biogas and meet the needs of rural clean



energy, it can be defined as utilization of straw resources inside the economic system in rural society. From the perspective that it can produce high quality and efficient organic fertilizer to soils, it can also be defined as recycle utilization of straw resources inside the agricultural production system. But from its proportion of matter conversion, and straw is converted into about 25% biogas and 75% biogas manure after fermentation at normal temperature, we should define it as recycle utilization of straw resources inside the agricultural production system, especially from the perspective that it can lengthen straw industrial chains and effectively promote the circular and highly-efficient utilization of straw resources.

The utilization effects of straw resources inside the agricultural production system can approximately boil down to three aspects as follows: firstly, application inside system of straw resources should combine the subsystem of crop cultivation and livestock breeding together, making it a key connection point for building circular economy system. Secondly, application inside system of straw resources is not only basic means to improve straw utilization rate, what's more, it can directly increase material and energy flow of 'crop cultivation-livestock breeding' system, making 'crop cultivation-livestock breeding' system healthier and more stable. Thirdly, straw resources can provide more agricultural products through transformation, at all levels, in the process of application inside system, most or partial nutrients return back to farmland at last which build a closed system of resource and economy among farmland, planting industry and breeding industry, it's beneficial to the health of farmland ecosystem. It's no need to say anything more about the profit of straw directly for fertilizer, straw for feeding can return to soils after eating by animals, straw for edible fungi cultivation can return to soils by generating high quality of organic bacterial manure, especially the modes of recycle utilization of straw such as 'straw-biogas', 'straw-livestock-feces-biogas' and 'straw-edible fungi-mushroom bran-biogas' which can not only produce clean energy but can also efficiently substitute for straw burning directly and generate high quality of organic manure to fields.

2. Utilization of straw resources inside the economic system in rural society

Utilization of straw resources inside the economic system in rural society primarily refers to utilization of straw for energy which is closely related to farmer's life, including development and utilization of rural new energy such as straw burning directly, straw gasification, straw solidification. The development and utilization of the straw resources for new energy can consume straw directly and substitute for burning straw directly, making the total consumption of burning straw appear a decreasing trend. At the same time, the development and utilization of the straw resources for new energy can substitute for coal, electricity, 'nature gas, liquefied petroleum gas, and gas' and some other commercial energies. According to the thermal efficiency of straw burning directly in realistic rural life and development and utilization of the straw resources for new energy, straw per ton on average for new energy exploitation can substitute for about 2 to 3 tons straw which are burned directly. The development and utilization of the straw resources for new energy will decrease the utilization quantity of straw resources outside the system and create conditions for the utilization of straw resources inside the system, but it will cause the increase of straw resources surplus at present.

3. Utilization of straw resources outside the economic system in rural society

Utilization of straw resources outside the economic system in rural society concludes straw industrial



processing, straw power generation and straw liquefaction.

Straw power generation and straw liquefaction belong to straw new energy doubtlessly and bring incomes for farmers through straw transaction. But from the perspective of its production aim, especially for straw power generation in scale, it doesn't aim to solve the energy problems of small-scale farmer household. Straw power generation provides electricity for farmers through converting straw into electricity which is collected from one family to another family. The production cost and energy efficiency of straw power generation are far more inferior to the ways of development and utilization for new energy such as straw biogas, straw gasification, straw solidification. Thus, it's justifiable for us to allocate straw power generation and straw liquefaction to utilization of straw resources outside the economic system in rural society.

Utilization of straw resources outside the economic system in rural society is the main development approach of straw industrialization in China. Utilization of straw resources outside the economic system in rural society has an important effect on improving the comprehensive utilization rate of straw resources in China and effectively solving the problem of straw burning and discarding as well as improving the development of straw industrialization. But the utilization of straw resources outside the economic system in rural society, no matter the utilization efficiency, both cause great drain of substance and energy of straw resources out of agricultural circular economy system, there will be few nutrients (based on K and P principally) which can return back to farmland eventually even when we pay attention to the utilization and collection of 'plant ash'. If straw resources outside the economic system in rural society are used excessively, it will cause each subsystem of agricultural ecosystem (including soil fertility subsystem, planting industry subsystem and breeding industry subsystem) disjoint from each other and will threaten cyclic development of agriculture.

III The main existing problems of straw resources comprehensive utilization in China

At present, utilization of straw resources in China still exists many problems such as comprehensive utilization insufficiency and utilization structure unreasonable, which are shown in five aspects as follows: ①The comprehensive utilization rate of straw is low. Without considering direct burning of straw, the comprehensive utilization rate of straw is lower than 45% at present. ②The problems of straw waste gas and straw burning are serious which bring about negative impacts on transportation, agricultural production and the life of people in rural and urban areas. Straw burning has become a social problem in China that hasn't be solved in a long term. ③The quantity of straw resources utilization inside agricultural production system is lower than that outside the system. In 2005, the total quantity of straw resources utilization inside agricultural production system in China is 253.89 million tons, which is 12.74% lower than the latter by 290.07 million tons. The former accounts for 46.67% of the straw that has been used in China and the latter accounts the rest 53.33%. ④Utilization of straw resources outside agricultural production system is based on the principle of burning straw directly, the quantity of straw for rural new energy exploiture is very limited, the quantity for 'straw gasification, straw solidification, straw carbonization, straw liquefaction and straw power generation' is less than 5 million tons. ⑤Utilization amount of straw resources outside the economic system in rural society is not high and the development of straw industrialization is still very week, which doesn't work most effectively to improve the comprehensive utiliza-



tion rate of straw resources. In 2005, utilization amount of straw resources outside the economic system in rural society in China is 50.52 million tons, which accounts for 7.36% of total quantity of collectible and available straw.

IV Using straw resources in an intensive, circulatory, highly-efficient and sufficient way

We can never let straw resources realistic utilization transfer to the low-efficient application, nor do harm to the sustainable development of agriculture and rural economy because of improper utilization, moreover, we can't let them burned and discarded optionally. Aiming at problems of straw resources realistic utilization and in order to set up new socialist countryside of resource-saving, environment-friendly and society-harmonious as early as possible, we must regard the intensive, cycle, highly-efficient and sufficient way of utilizing straw resource as general direction. According to the local conditions and overall planning coupled with allocating straw resources rationally and optimizing straw utilization structure, it should not only use straw resources rationally enough but also avoid repeated construction and unnecessary competition. The utilization demand inside agricultural production system and economic system in rural society should be preferential satisfied and the utilization demand outside economic system in rural society follows. Supporting by science and technology and innovation mechanism, bringing the supporting function of science and technology advancement to straw comprehensive utilization into full play, it should constantly improve the utilization rate and efficiency of straw resources and gradually decrease the consumption of straw burning directly, and at last solve the problems of straw burning and discarding fundamentally and guarantee the sustainable development of agriculture and rural economy.

1. Regarding straw returning to field, straw for livestock breeding and edible fungi cultivation as the main orientations, we should try our best to increase the utilization quantity of straw inside the agricultural production system through an intensive, circular and highly-efficient way of utilizing straw resources

Circular agriculture is an important way for sustainable development of agriculture and rural economy in China. From this point, utilization of straw resources must satisfy the demand inside agricultural production system firstly. At present, demand deficiency is severe for the inner utilization of straw resources. Soil fertility subsystem, planting industry subsystem and breeding industry subsystem disjoint from each other, causing problems of soil hardening, quality of agricultural products degeneration and eutrophication of water bodies much more severe. From the point of fertilizing soil, the utilization quantity of straw inside agricultural production system should account for more than 50% of total quantity of collectible and available straw. So, we should encourage and support the application of straw as a kind of resource for fertilizer, feed and edible fungi cultivation. We should energetically develop straw returning and to add soil nutrient, fertilize land productivity, promote agriculture increasing production and efficiency as well as improve the quality of agricultural products and food security on the base of making full use of straw resources which is organic fertilizer. The emphasis is to popularize the matching mechanism and technology for returning straw to soils and the technology for straw quick composting to soils and bioreactor landfill. In areas suitable for no-tillage, we should develop conservation tillage of straw actively and focus on the technique extension of no-tillage, straw mulching and light planting based on the reality that enormous outflow of rural labor force. Straw organic fertilizer processing factory should be encouraged to set up. We



should actively develop animal husbandry and convert straw into high-quality feed through ensiling, ammoniation, micro-storage, briquetting, kneading and silken and some other treatment methods. Then we can exchange straw for meat and milk and guarantee the supply of animal products and food security. At the same time, we should actively develop the production of edible fungi which uses straw as base material. We should actively develop biogas, and lengthen straw industrial chains, and coordinate the relationship between straw utilization inside agricultural production system and straw exploitation for new energy, and produce more biogas manure returning to field.

2. Enhancing rural straw exploitation for new energy and using straw resources in an intensive and high-efficient way, it must satisfy the needs of utilizing straw resources inside economic system in rural society, and the consumption of straw burning directly decreases gradually

Although China has just made a start in the development and utilization of the straw resources for new energy, it has been received by farmers and become an object for governments at all levels to build new socialist countryside because of its high public welfare and social influence. Thus, we should advocate and support for the straw resources utilization new energy, combining setting up new socialist countryside with regulating rural environment, developing straw gasification, straw solidification and straw carbonization actively. Then we can make it toward marketization and industrialization and substitute the straw new energy for straw and firewood burning directly and also substitute for coal and some other fossil energy.

3. Arranging the straw utilization outside economic system in rural society rationally and setting up a industrialization system which refers to further development of straw resources as the core, we should use straw resources in an intensive and highly-efficient way, and then convert straw resources advantage into economic advantage to drive regional economic development, moreover, we can make full use of the straw resources

We should steadily push the development of processing industry based on straw: Popularizing cleaner technology of straw pulp papermaking, and encouraging and supporting for zero-emission papermaking by straw and solving the environment pollution of straw pulp papermaking. We should actively develop the production of building materials, packaging material and tableware which use straw as raw material, with which can substitute for wood and lessen the pressure of vegetations and forests. We should also actively develop processing industry of straw products. According to the development requirement of regional social economy, on condition that ensure the prior satisfaction of utilization demands inside agricultural production system and economic system in rural society in areas that distribution density of straw resource is higher. We should bring the positive function of straw power generation on straw discarded into full play, distribute straw power plant rationally, combine many ways of straw power generation together such as straw-fired power generation of big, medium or small scale, blend-fired power generation, gasification power generation, and we also need to develop green energy and to improve the utilization rate and utilization efficiency of straw effectively. For straw power generation, it must develop in proper amount, the more important is to distribute rationally, avoiding blind development and forbidding jumping on the bandwagon. Responsible institutions at all levels should treat straw power generation with caution, especially for the approval of large and middle straw projects. Otherwise, large-scale straw centralized collection and predatory utilization must threaten the circular utilization of straw resources inside agricultural



production system. At the same time, aiming at problems that straw production is dispersive, strong seasonality, easy to decay, high cost of collection and storage, large area occupied and some other problems, we should try to set up straw collection and logistics system which led by enterprises, farmer participation, supervised by country and township government, pushed by marketization, and to set up a necessary management system of straw storage. The emphasis is to encourage straw bundle storage, especially to encourage mechanized combined operation which is integrated with crop harvest and storage transportation.

V General trend of straw resources comprehensive utilization in China

‘Four Increases’, ‘Two Decreases’ and ‘One Substitution’ are the concrete embodiments of the general trend of straw resources comprehensive utilization in China. ‘Four Increases’ means that: ① Increase of straw utilization for new energy. ② Increase of straw for feed. ③ Increase of straw utilization quantity for straw industrial processing. ④ Increase of straw utilization quantity for edible fungi cultivation. ‘Two Decreases’ means that decrease of straw burning and discarding until no burning and discarding and decrease of straw burning directly. ‘One Substitution’ means that straw returning directly will be substitute by returning straw to soils after eating by animals, biogas manure or straw biogas manure after eating by animals. Straw returning directly is the most shortcut approach that can batch processing most straw, and in order to solve the problems of straw burning and discarding, there must be a dramatic rise in the quantity of straw returning in the near future. But on a long view, the quantity of straw returning directly will appear a decreased trend along with the increase of the quantity of substitution.

By the year 2010 and 2015, the quantity of straw returning to soils is forecasted to reach 0.1 billion tons and 0.13 billion tons, respectively, and the newly added quantity of straw returning to soils per year on average is about 6.5 million tons. Straw for feed will reach 0.227 billion tons, and 0.277 billion tons respectively, the newly added quantity of straw for feed per year on average is 10 million tons, straw for livestock cultivation will reach 0.57 billion tons and 0.7 billion sheep units respectively. Straw quantity for rural new energy (including straw biogas, straw gasification, straw solidification, straw carbonization) exploitation will reach more than 2.6 million tons and 50 million tons respectively. Utilization quantity of straw power generation will reach 10 million tons and 30 million tons respectively. Utilization quantity for straw industrial processing will reach 61.5 million tons and 78 million tons respectively. Straw utilization quantity for edible fungi cultivation will reach 14 million tons and 21.6 million tons respectively. Meanwhile, the quantity of straw burning directly in China will decrease to 0.185 billion tons and 0.12 billion tons, respectively.

From the three systems of straw utilization, the straw utilization quantity inside agricultural production system will increase from 253.89 million tons to 342.06 million tons and 434.95 million tons respectively from the year 2005 to 2010 and 2015, and the net increase quantity is 88.17 million tons and 181.06 million tons, respectively, and the proportion of collectible and available straw will increase from 37.01% to 49.12% by 2010 and 61.07% by 2015. Along with dramatic decrease of straw burning directly, the straw utilization quantity inside economic system in rural society in China will decrease from 239.57 million tons to 186.35 million tons and 169.24 million tons, the net decrease quantity is 53.22 million tons and 70.33 million tons, respectively, the proportion of which in collectible and available straw will decrease from 34.93% to 26.76% and 23.76%, respectively. The utilization quantity of



straw outside economic system in rural society will increase from 50.52 million tons to 71.5 million tons and 108 million tons, and the net increased quantity is 20.98 million tons and 57.48 million tons, respectively, and the proportion of which in collectible and available straw will increase from 7.36% to 10.27% and 15.16%.

Through straw comprehensive utilization, residual straw will decrease to less than 0.1 billion tons by the year 2010, and the problems of straw burning and discarding will be basically solved by the year 2015. On condition that we don't take straw burning directly into account, the straw comprehensive utilization rate will reach about 60% and more than 80%, respectively.

Authors

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