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Study on Forest Landscape Restoration

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序　言

森林是陆地生态系统的主体，同时具有生态、经济和社会等方面的多种效益，在保障国家生态环境安全、丰富林产品供给、促进农村和林区的增收就业、改善人民生活质量等方面具有独特的作用。但是近百年来的过度采伐以及土地利用方式的改变在造成大面积森林景观消失的同时，也带来了森林的退化或破碎化问题，导致森林生产力下降、森林生境破碎化、乡土树种加速灭绝、环境质量下降、农村贫困和社会冲突等一系列问题的产生。森林景观恢复（FLR）的提出，为恢复退化森林景观、提高居民福利，促进森林可持续经营和经济社会的可持续发展提供了一种新的途径。作为一种森林可持续经营的补充框架，森林景观恢复涉及景观生态学、森林生态学、利益相关者理论、公众参与机制、适应性经营和森林经理学等多学科的知识，是多种方法和技术的融合运用。

在国际社会日益重视森林景观恢复的同时，我国已于2008年3月加入森林景观恢复全球伙伴关系，但是对森林景观恢复这一概念和途径本身，对国际上森林景观恢复的实践经验和教训，以及对森林景观恢复的技术与方法体系，我国还缺乏一个比较完整和系统的研究。本著作是国内第一部系统研究森林景观恢复理论与技术体系的专著，著者以海南省陵水黎族自治县和大敢FLR社区为研究案例，从区域水平和社区水平构建了符合我国实际的森林景观恢复内容与方法体系，其中区域水平森林景观恢复的提出是对社区水平森林景观恢复的重要补充。相信这部《森林景观恢复研究》的出版，必将受到林学或其他相关专业的科研人员和林业基层工作人员的欢迎，并为促进我国森林景观恢复工作的深入开展和区域经济社会的可持续发展做出重要贡献，特为序。

中国科学院院士 [signature]

2010年12月

前 言

森林作为陆地生态系统的主体，不仅是生物圈中的重要生产者，在维持全球碳循环、维护保护区域生态安全方面发挥着不可替代的作用，而且是重要的物种栖息地和人类生存必需的原材料、食物、药物、能源等的重要来源。但是，近百年来过度采伐以及土地利用方式的改变造成大面积森林景观消失的同时，也带来了森林的退化或破碎化问题，导致森林功能的丧失、景观平衡的破坏、森林结构的变化及生物多样性的降低、林产品和服务的不平等分配、农村贫困、社会冲突等一系列问题的出现。为应对以上问题，1999 年，世界自然保护联盟（IUCN）和世界自然基金会（WWF）以及其他一些组织，提出了“森林景观恢复”的途径，以面对恢复退化或修正（Modified）森林景观的产品和服务的挑战。2001 年，IUCN、WWF、国际热带木材组织（ITTO）及其他一些非政府组织提出了森林景观恢复（FLR，Forest Landscape Restoration）的概念。为了将森林景观恢复的思想落实为行动，IUCN、WWF 和大不列颠森林委员会于 2003 年 3 月在罗马发起了森林景观恢复全球伙伴关系（The Global Partnership on FLR），提供了一个在全世界范围内分享经验和相互学习的工具。

森林景观恢复提供了一种森林可持续经营的补充框架，是在毁林或森林退化导致生态系统服务质量下降的景观内实施的生态系统方法。目的不是重建森林的原始状态（即使这是可能的），而是加强景观的恢复能力，从而保持未来经营选择的开放，同时支持社区维持和提高从森林经营中获得的效益。作为履行国际上在森林、生物多样性、气候变化和荒漠化方面各项商定承诺的一个途径，森林景观恢复在国际上已经受到了广泛的关注。在 IUCN、WWF、ITTO 等国际组织的推动下，许多国家和地区正在积极开展森林景观恢复的实施和研究工作。但是，对森林景观恢复这一概念和途径本身，对国际上森林景观恢复的实践经验和教训，以及对森林景观恢复的技术与方法体系，我们还缺乏一个比较完整和系统的研究，因此很容易走进照搬其他国家的具体实践，或者认为等同于森林恢复、生态系统恢复、社区林业等概念而拒绝接受森林景观恢复的局面。

实际上，我国在森林恢复方面已经积累了丰富的经验，如天然林资源保护和退耕还林等重大林业工程的实施。相关学者也开展了参与式林业、森林资源监测与评价、营造林技术、森林景观格局分析、生态恢复等方

面的大量研究，而这些正是森林景观恢复的理论基础和其中涉及的方法。同时，我国在2008年加入了森林景观恢复全球伙伴关系，将森林景观恢复纳入国家决策层面。因此，不论从理论角度还是从实践角度探索森林景观恢复都是我国学者面临的一个新课题。

本著作以海南省陵水黎族自治县和大敢森林景观恢复（FLR）示范区为研究对象，从区域与社区水平研究了适合中国国情与林情的森林景观恢复（FLR）技术。在系统介绍了森林景观恢复的背景起源、基本概念和内涵的基础上，分析总结了国内外森林景观恢复的研究现状和趋势，构建了森林景观恢复的内容与方法体系，包括利益相关者分析、建立FLR支持、景观镶嵌体与动态分析、确定优先恢复立地选择及优先恢复立地、制定立地水平恢复策略、FLR规划与实施和监测与评价等内容；通过建立基于森林景观恢复的景观要素分类体系，研究区域水平和社区水平基础数据的获取方法，重点分析了陵水黎族自治县和大敢FLR示范区的景观格局现状与动态；利用不同时期的转移概率矩阵，结合参与式方法分析了区域与社区水平森林景观变化的驱动力；选择典型的退化与次生森林，详细分析退化原始林、次生林、退化林地等不同森林类型的测树学和群落学特征，在此基础上研究了其立地水平恢复策略；最后通过参与式农村评估（PRA）方法在社区水平的实地应用，研究了PRA在森林景观恢复中的应用技术。

本著作是国际热木材组织ITTO PD423/06Rev.2(F)项目“ITTO森林景观恢复手册在中国热带地区的示范培训、应用与推广”的研究成果，本著作的出版得到国际热带木材组织ITTO PD423/06Rev.2(F)项目和中国林业科学研究院中央级公益性科研院所基本科研业务费专项资金CAF-YB B2007001项目的资助。本著作在撰写过程中得到仝慧杰教授/博士、黄金城博士、瑞士Intercooperation的Juergen Blaser博士和James K. Gasana博士、德国慕尼黑理工大学森林经理研究所的Tomas Knoke教授/博士，海南省林业局丁长春、何楚林、谢明东、田爱英和陵水黎族自治县林业局梁有豪、杨克仁等林业工作者，以及群英乡邱进文和大敢村全体村民的帮助，在此深表感谢。

限于著者水平，书中难免存在这样或那样的不足，敬请广大读者批评指正。

著 者

2010年12月

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第一章 绪　论

1.1 森林景观恢复的背景和起源

森林是陆地生态系统的主体，同时具有生态、经济和社会等方面的多种效益，在保障国家生态环境安全、丰富林产品供给、促进农村和林区的增收就业、改善人民生活质量等方面具有独特的作用。但是近百年来的过度采伐以及土地利用方式的改变造成大面积森林景观消失的同时，也带来了森林的退化或破碎化问题(Maginnis S 和 Jackson W，2002；IUCN 和 WWF，2005；FAO，2005)。具体体现在：

(1)森林总面积继续减少，尽管净损失的速度在减缓。联合国粮食及农业组织(FAO)《2005 年全球森林资源评估》报告指出，2000～2005 年全球森林面积每年消失 730 万 hm^2，相当于年均损失 0.18% 的森林面积，比 1990～2000 年每年消失 890 万 hm^2 略有减缓。

(2)现有森林严重退化、生产力下降。IUCN 指出，世界森林有一半以上已经退化，原始林以每年 600 万 hm^2 的速度消失或发生改变，联合国粮食及农业组织(FAO)《2000 年全球森林资源评估》报告显示，亚洲有 1.4 亿 hm^2 以上的原为森林的林地，现在已衰退为灌木林，或由于地表植被覆盖的减少而不能继续算作森林(FAO，2005)，引起木材、纤维、能源与生物质供应能力下降、水质恶化、生物多样性锐减的问题。

(3)森林向破碎化、修正化趋势发展。农业用地扩张和集约化经营，导致现有森林结构简化，大片森林被分割成更小的、孤立的块状(Kaiser J，2000)。仅热带地区就有 8.3 亿 hm^2 的森林以破碎化形式存在，其中约有 5 亿 hm^2 的退化原始林或热带次生林只能被认作修正后的森林景观，修正森林景观内还有 4 亿 hm^2、有明显树种组成的农业用地(ITTO 和 IUCN，2005)。

(4)次生林、已退化土地面积增加。原始林退化后，就可能出现各种次生林，甚至出现不具备次生林更新、超出森林自我恢复能力的已退化土地，这些区域几乎丧失了所有的森林属性(结构、功能、生产力、组成)(ITTO，2002)，见表 1-1。

表 1-1 2000 年亚、美、非洲热带地区退化、次生林面积估计(亿 hm^2) [①]

类型	亚洲/17 国	美洲/23 国	非洲/37 国	总计
退化原始林和次生林	1.45	1.8	1.75	5
退化林地	1.25	1.55	0.7	3.5
总计	2.7	3.55	2.45	8.5

①来源：FAO(1982, 1993, 1995, 2001)。

(5)气候变化。世界森林仅在其生物量中便储存着2830亿t碳，而森林生物量、朽木、森林凋落物和土壤中碳的总储量相当于大气中碳含量的50%以上，在1990～2005年间，非洲、亚洲和南美洲森林生物量中的碳储量一直在减少(雷加富，2005)。就全球而言，森林生物量中的碳储量每年减少11亿t，即每年约有11亿t碳逸入大气。大气中的CO_2增加导致温室效应的加剧。

(6)生计困难。所有上述问题都影响到以森林为生的居民的生活，尤其是从森林中获取食物、燃料、建筑材料及其他必需品的贫困居民。他们的农地非常有限，主要依靠森林作为社会保障，脱离森林后，社会和经济问题随之出现。

(7)森林审美和文化价值丧失。随着森林面积的减少和森林的退化，健康森林所具有审美和文化价值也不复存在。

针对这些问题及其产生的原因，许多国家在经营和保护森林面积的完整方面做出了很大努力，各种恢复方法如耕作制度、生计可持续途径、生态系统方法、综合自然资源经营(Carney D, 2005; Campbell B M, 2003)等也相应产生。但是传统的森林恢复方法仍有许多的局限性。首先，传统恢复方法在面对森林退化和地区贫困的双重问题时，往往是牺牲其中一方来解决另一方，但是这种对策并不能真正解决问题，例如，为改变某一地区森林退化的现状，恢复重点放在提高森林生态效益上，却不能为依赖森林维持生计的居民带来明显收益(至少在短期内是如此)，结果可能导致周围居民破坏最新恢复的森林，甚至砍伐天然更新的森林用作农业用地，再次造成森林的退化，形成恶性循环(IUCN 和 WWF, 2005)；其次，局限于再造林的传统方法大多是基于立地水平的干预，从而忽视了景观水平上的目标(IUCN, 2004)。传统恢复退化森林的方法仅停留在一些小的、局部的立地水平内，恢复活动的重点是人工造林，而且多数人工林造林所选树种有限，其目的仅仅是为了获得一两种产品，而不是更为广泛的森林产品以及能提高社区生活水平的服务(Dobson A 等, 1997)。一般的造林方式很难提供多种森林价值并充分

满足所有相关利益者(例如，靠森林为生的社区和河流下游的水资源使用者)的各种需求。这些方法在恢复早期成效显著，但随着恢复过程的发展，就会出现许多超出人们预料的新问题，甚至导致恢复活动的前功尽弃(Ashworth S M，1997)。

因此，更加全面的恢复途径应该是以更广的环境、社会、经济需求为背景，强调森林的质量和数量，需要在恢复森林生态完整性的同时也为当地居民带来切实利益。森林景观恢复(FLR，forest landscape restoration)就是在这种背景下兴起和发展起来的(Maginnis S，2002；Aldrich M和Sandeep S，2005)。1996年，WWF和IUCN发起了“生命之林(forest for life)”项目，提出恢复森林的明确目标，这是森林景观恢复倡议(FLR initiative)的起点。1998年，IUCN对越南、老挝、柬埔寨、泰国的森林恢复活动进行了总结，随之与这四个国家政府的对话，拓宽了有关恢复活动合理性的思想和观念(Gilmour D A，2000)。1999年，WWF和IUCN建立了森林更新计划；2001年，IUCN、WWF及其他一些非政府组织提出了森林景观恢复的概念。

1.2 森林景观恢复的基本概念与内涵

1.2.1 森林景观恢复

“森林景观恢复(FLR)”一词第一次定义是在2001年，由聚集在西班牙塞哥维亚(Segovia)的森林恢复专家提出，定义为：森林景观恢复是一个旨在恢复伐后森林景观或退化森林景观的生态完整性和提高人类福利的过程(Maginnis S，2005；Maginnis S和Jackson W，2005；Mansourian S，2005)。

定义体现了森林景观恢复的4个主要特征：①FLR是一个过程：“过程”一词有3个主要原则：参与式；建立在适应性经营基础上，从而及时对社会、经济、环境的变化做出响应；需要一个清晰连贯的评价和学习框架。②FLR试图恢复生态完整性：在整个景观上重建森林功能的一个或两个方面是不够的(只能满足部分利益相关者的需求)，也是不可持续的(很难响应社会、经济、环境的变化)。③FLR试图提高人类福利：提高生态完整性和居民福利不能在景观水平上折衷。④FLR在景观水平上实施：并不表明森林景观恢复只能在大尺度上实施，而是在景观框架下做出立地水平的决定(Soutsas K，2004)。

森林景观恢复全球伙伴关系拓宽了此定义的理解：森林景观恢复旨在恢复退化土地的生态完整性，提高其生产力和经济价值，而不是重建

过去的"原始(pristine)"森林；FAO对森林景观恢复的定义包括"森林重建(forest rehabilitation)"；Maginnis(2003)认为此定义的重点是恢复景观尺度上的森林功能，而不仅是依靠增加某个地方的森林面积；巴西彼得罗波利斯研讨会强调森林景观恢复是一个工具，是通过建立互补的土地利用镶嵌体，而不仅是各成分的简单相加，从而实现更加多样化的景观目标。

1.2.2 相关概念

1.2.2.1 森林景观

景观(landscape)一词的原意是表示自然风光、地面形态和风景画面，作为科学名词被引入地理学和生态学，则具有地表可见景象的综合与某个限定性区域的双重含义(肖笃宁，1999)。景观的定义有多种表述，但大多是反映内陆地形、地貌、景色的(诸如草原、森林、山脉、湖泊等)，或是反映某一地理区域的综合地形特征(邬建国，2000)。目前人们更多地接受景观地生态学概念，即景观是一个由不同土地单元镶嵌组成，且有明显视觉特征的地理实体；它是处于生态系统之上，大地理区域之下的中间尺度，兼具经济价值、生态价值和美学价值。郭晋平(2001)认为景观的现代概念包括四个特征：景观是一个生态系统，具有系统整体性；景观是具有一定自然和文化特征的地域空间实体；景观是异质生态系统的镶嵌体；景观是人类活动和生存的基本空间。

森林景观(forest landscape)是以森林生态系统为主体的景观，也包括森林在景观整体格局和功能中发挥重要作用的其它类型的景观。Maginnis(2002)认为森林景观是(或曾经是)以森林或林地为主，能产生林产品和服务的景观(Maginnis S和Jackson W，2002)。

1.2.2.2 森林退化

森林退化(forest degradation)是个比较模糊的概念，也是一个主观性很强的术语。FAO定义森林退化为"逆向影响林分或立地的结构或功能从而降低森林提供产品和服务能力的森林内的变化过程"(FAO，2000)。WWF采用了FAO的定义。ITTO定义森林退化为"森林潜在效益的全面、长期降低，包括木材、生物多样性和任何其它产品或服务"(ITTO，2002)。联合国生物多样性保护公约(UNCBD)则定义退化森林是"由人类活动引起的、丧失原有天然林正常的结构、功能、物种组成或生产力的次生林"(UNEP/CBD/SBSSTA，2001)。

1.2.2.3 景观恢复

"景观恢复(landscape restoration)"一词出现较晚，要理解它首先要

理解生态恢复(ecological restoration)。Cairns 等将生态恢复的概念定义为：恢复被损害生态系统到接近于它受干扰前的自然状况的管理与操作过程，即重建该系统干扰前的结构与功能及有关的物理、化学和生物学特征(许木启，1998)。美国生态学会（Society for Ecological Restoration）则认为：生态恢复就是人们有目的地把一个地方改建成定义明确、固有的、历史的生态系统的过程，这一过程的目的是竭力仿效那种特定生态系统的结构、功能、生物多样性及其变迁的过程(赵平，1999)。这些定义都未探讨生态系统与周围环境的关系，仅从生态系统尺度上进行生态恢复与重建，并未达到真正意义上恢复与重建的目的。因此，生态恢复要诉诸于景观途径。

Hobbs R J(1996)提出景观恢复是从景观尺度上考虑恢复，它是指恢复生态系统间被人类活动破坏或破碎的自然联系。这表明，景观恢复不是仅局限于某个生态系统，而注重了景观格局及其各要素间的功能联系，在更大尺度上实现生态恢复的目标。

1.2.2.4 生态完整性

Woodley(1993)提出生态完整性(ecological integrity)的含义是：生态系统的自然演化代表了世界发展的最佳模式，促进了生态系统多样性和复杂性，并为人类提供了不可估量的利益，这个宝贵的自然“完整性”值得我们来保护。也有学者认为生态完整性就是维持生态系统的多样性和质量，提高生态系统适应变化的能力，以满足下一代需求(Lamb D，2003)。

1.2.2.5 人类福利

人类福利(human well-being)是一个广义的术语，它不仅包括林产品和生态服务的市场价值所产生的效益，也包括由此带来的所有效益。Fisher 描述人类福利的要素为：以物质产品形式产生的经济效益，物质产品包括资产、资本、可利用劳动力、信贷和可支配现金；生活要素如健康、教育、文化等的质量；公平，即福利在个人、团体间的分配是否公平(“公平”不等于“平等”)(Fisher 等，1996)。

1.2.2.6 双重过滤器

森林景观恢复定义强调在景观尺度上恢复长期的生态完整性和提高人类福利，这一原则被称为森林景观恢复的“双重过滤器(double-filter)”(ITTO，2005)。“双重过滤器”承认立地水平上经济、社会和保护价值之间的折衷，但是任何立地水平上的折衷必须满足景观尺度上经济效益、社会效益和环境效益的平衡(Marghescu T，2001)。

1.2.3 与传统恢复方法的区别

传统恢复方法如耕作制度、生计可持续途径、生态系统方法、综合自然资源经营等已经建立起一套恢复某些困难立地的经验(Carney D, 2002; ITTO, 2005)，因此并不缺乏实施森林景观恢复的知识，通常缺乏的是对整个景观的理解或对景观内居民福利的考虑。从本质上看，森林景观恢复是一种管理构成景观的人、自然资源和土地利用之间的动态、复杂的相互作用的方法，通过相互协商与相互合作，协调利益相关者之间不同的土地利用，旨在恢复生态完整性，促进当地社区和整个国家的经济发展。它与传统恢复方法的区别表现在(表 1-2)：采用景观水平的观点，这并不意味着任何森林景观恢复倡议都必须是大规模的、高成本的活动，而是立地水平的恢复决定需要考虑对景观水平的影响，满足景观水平的目标；在“双重过滤器”约束下执行，即恢复结果要在景观水平上恢复生态完整性，提高人类福利；是一个合作过程，涉及最大范围的利益团体，共同制定技术上最合适的、社会经济可接受的恢复选择；目的并非还原森林景观的“原始”状态，而是一种旨在加强森林景观恢复能力的前瞻性方法，以增加未来的选择余地，实现景观水平上林产品和服务的最优化；不仅适用于原始林，也适用于次生林、林地甚至农业用地(ITTO 和 IUCN, 2005)。

表 1-2 森林景观恢复与相似方法的比较

主要指标	耕作制度	生计可持续途径	生态系统方法	综合自然资源经营	森林景观恢复
起源	发展	发展	保护	研究	保护
目标	参与式发展	减少贫困	生物多样性保护和可持续发展	可持续发展和提高生产力	镶嵌景观中的生物多样性保护
特有成分	参与式和对系统的整体考虑	生计	面向过程的保护	过程定位，科学与政策的关系	林业和过程定位实地技术与政策的关系
干扰水平	地方	地方	立地内外	按比例放大的系统	重点是立地—景观的相互作用
主要使用者	非洲法语国家(过去)	英语国家	项目经理	研究人员，项目经理，农民	林业工作者
实施现状	已过去	开始有效实施	进展缓慢	最近开始	最近开始

引起森林景观恢复区别于其它以恢复为导向的技术方法的主要原因是：森林景观恢复强调如何最好的恢复森林功能(产品、服务、过程)的恢复决定，而不是使森林覆盖率最大，换句话说，森林景观恢复不只是种树；鼓励实施者制定景观水平内的基于立地的决策，至少保证这些决策不降低景观水平内森林功能的数量或质量，即这些决策应利于提高整个景观的功能性；强调当地需要、平衡恢复需求和国家政策，将当地利益相关者参与计划和经营决策视为森林景观恢复的重要部分；促进立地水平恢复的同时，强烈反对引起景观水平上人类福利和生态完整性折衷的活动，因为这种折衷是不可持续的；承认不能准确预测复杂的土地利用及活动的产出，尤其是生态系统和土地利用格局随时间变化时，因此森林景观恢复建立在适应性经营的基础上，需要不断的监测和学习；由于恢复活动的复杂性，森林景观恢复需要一套工具，单一的方法不能为实施者提供足够的灵活性；从长远来看，森林景观恢复不仅靠完善的技术干预来推动，更需要地方和国家政策的支持，实施者需要熟悉其它土地利用政策对森林恢复的影响(Lamb D，2003；Maginnis S，2005)。

1.3　森林景观恢复的理论基础

森林景观恢复的理论基础主要涉及：景观生态学、恢复生态学、利益相关者理论、公众参与和适应性经营。

1.3.1　景观生态学

景观生态学是研究一个相当大的区域内，由许多不同生态系统所组成的整体(即景观)的空间结构、相互作用、协调功能及动态变化的一门生态学新分支(肖笃宁，1999；傅伯杰等，2001)。景观生态学目前正在各行各业的宏观研究领域中以前所未有的速度得到接受和普及，成为世界上资源、环境、生态方面研究的一个热点，它注重人类活动对景观格局与过程的影响，退化和破坏了的生态系统和景观的保护与重建也是景观生态学的研究重点之一。景观生态学理论可以指导退化生态系统恢复实践，如为重建所要恢复的各种要素，使其具有合适的空间构型，从而达到退化生态系统恢复的目的；通过景观空间格局配置构型来指导退化生态系统恢复，使得恢复工作获得成功。景观生态学中的核心概念和其一般原理斑块形状、生态系统间相互作用、镶嵌系列等都同退化森林的恢复有着密切的关系。

1.3.1.1　景观异质性

异质性是景观的根本属性，一个景观生态系统的结构、功能、性质

和地位主要取决于它的时空异质性(肖笃宁等，1997)。时空异质性的交互作用是导致景观生态系统的演化发展和动态变化的根本原因。在景观的异质性研究中，我们最为直接关注的是景观的空间异质性，它直接决定了景观的格局、结构及功能现状，而正是景观的时空异质性的交互作用导致了景观系统的演化发展和动态平衡性(田亚平，2004)。景观异质性指数可以用于比较两个景观的差异，确定景观异质性是如何影响景观的结构、功能与过程的。景观异质性指数可以分为四大类：多样性指数、镶嵌度指数、距离指数、生境破碎化指数。

1.3.1.2 景观格局

景观格局是指大小或形状不同的斑块在景观空间上的排列(邬建国，2000)。它是景观异质性的具体表现，同时又是包括干扰在内的各种生态过程在不同尺度上综合作用的结果(贾宝全等，2001)。研究景观格局的目的是在似乎是无序的景观斑块镶嵌中，发现其潜在的规律性，确定产生和控制空间格局的因子和机制，比较不同景观的空间格局及其效应。景观的空间结构影响着干扰的扩散和能量的转移，具有较大优势的斑块，对其它斑块的转化有较大影响。如土地退化景观的优势扩大，说明景观格局向较差的方向发展，最终可能形成荒漠化景观；反之，则说明退化景观的恢复治理效果较好(宋豫秦等，2000)。

1.3.1.3 干扰

景观可以看作是干扰的产物。景观格局变化的原因就在于对景观要素的干扰作用，这些干扰作用往往是综合的，包括自然环境、各种生物以及人类社会之间复杂的相互作用，其结果是景观系统内个别要素的稳定性和景观的空间结构发生变化。中度干扰一般可在景观中产生较多的景观镶嵌体或廊道，而严重干扰则可能消除许多镶嵌体和廊道，从而形成一个更为均质的沙地景观，或者是均匀的植被被消除而裸露出其下的异质性基底。生态系统退化实际上就是一个系统在超载干扰下逆向演替的生态过程，生态系统退化的根本驱动力，是人类直接或间接干扰(章家恩和徐琪，1999)。

1.3.1.4 尺度

景观格局和景观异质性都依我们所测定的时间和空间尺度变化而异，离开尺度来谈论景观的异质性、格局、干扰是无意义的(徐化成，1996)。对于生态系统的退化及其恢复与重建的认识，不能仅仅局限于生态系统，应该是跨尺度、多等级的问题，其主要表现层次应是生态系统(生物群落)、景观，甚至区域。生态系统与景观，简单地说是尺度

上的差异，景观可以看成是生态系统的集合，景观中的斑块是一个与包围它的生态系统截然不同的生态系统。仅从生态系统这一尺度上进行生态恢复与重建不能达到真正意义上恢复与重建的目的，必须考虑周围景观的影响，采取相应措施来减少周围景观产生的负面效应，否则，局限在小面积内的单一物种保护的生态恢复措施肯定会失败。

1.3.1.5　景观结构镶嵌性

各种景观要素斑块交错分布，有机地结合在一起就形成了景观镶嵌体(Lamb D 和 Gilmour D，2003)。作为镶嵌体的景观按其所含的斑块粒度—用斑块平均直径量度，可区分为粗粒和细粒景观。镶嵌性是研究对象聚集或分散的特征，在景观中形成明显的边界，使连续的空间实体出现中断和空间突变(郭晋平，2001)。景观是一个由不同生态系统组成的镶嵌体，镶嵌结构是景观的最主要特征之一，Forman(1995)认为景观生态学的实质就是研究景观镶嵌体的结构，他提出的斑块—廊道—基质模型即使对此的一种理论表述(肖笃宁，1999)。

景观生态学的“斑块—廊道—基质”(PCM)模式就是以斑块、廊道、基质为核心的一系列概念、理论和方法。按照景观要素在景观中的空间形态、轮廓和分布等基本特征，可以区分出斑块、廊道、基质三种空间类型。斑块是外貌上与周围地区(基质)有所不同的一块非线性地表区域，但又具有一定的内部同质性，斑块包括植物群落、湖泊、草原、农田等，因而其大小、类型、形状、边界以及内部同质程度都会显现出很大的不同。廊道是指景观中与相邻两边环境不同的线性或带状结构，常见的廊道包括农田间的防风林带、河流、道路、峡谷等，廊道类型的多样性，导致其结构和功能方法的多样化，其重要结构特征包括：宽度、组成内容、内部环境、形状、连续性以及与周围斑块的作用关系。廊道常常相互交叉形成网络，使廊道与斑块和基质的相互作用复杂化。基质则是指景观中分布最广、连续性最大并且在景观功能上起着优势作用的背景结构。常见的有森林基质，草原基质，农田基质，城市用地基质等等，在许多景观中，其总体动态常常受基质所支配(徐化成，1996)。斑块的大小、形状和边界，廊道曲直、宽窄和连接度，基质的连通性、孔隙度、聚集度等，构成了镶嵌特征丰富多彩的景观格局。

1.3.2　恢复生态学

恢复生态学是研究生态系统退化的原因、退化生态恢复与重建的技术与方法、生态学过程与机理的科学，是一门以基础理论和技术为软硬件支撑的多学科交叉、多层面兼顾的综合应用学科，是森林植被恢复重

建的重要理论基础。近年来，恢复生态学研究主要涉及两个方面：一是对生态系统退化与恢复的生态学过程，包括各类退化生态系统的成因和驱动力、退化过程、特点等；二是通过生态工程技术对各种退化生态系统恢复与重建模式的试验示范研究。主要研究目标是恢复被损害的生态系统到接近于它受干扰前的自然状况，即重建该系统干扰前的结构与功能有关的物理、化学和生物学特征(Hobbs R J，1996；IUCN，2004)。在森林景观恢复理论和方法中运用到的恢复生态学理论包括：

1.3.2.1 生物群落演替理论

群落的自然演替机制奠定了恢复生态学的理论基础。演替可以在地球上几乎所有类型的生态系统中发生，有两种基本类型：原生演替和次生演替，次生演替序列可通过人为手段加以控制，加快演替速度，退化生态系统的恢复就是生态系统中的次生演替过程。与自然条件下发生的次生演替不同，生态恢复强调人类的主动作用。在自然条件下，如果群落一旦遭到干扰和破坏，它还是能够恢复的，尽管恢复的时间有长有短。一般来讲，对于一个生态破坏严重的生态系统，生物种类及其生长介质的丧失或改变是影响生态恢复的主要障碍，对于这一关键问题，通常采用选择合适的植物种类改造介质，使被破坏的生态环境变得更适合其他更多植物的生长，这样可以大大加速生态系统的重建(臧润国和刘静艳，1998)。因此，选择适宜的植物种类是退化生态系统恢复与重建的关键技术之一。

1.3.2.2 生态位原理

生态位是指在生态系统或群落中，一个种与其它种相关联的特定时间位置、空间位置和功能地位等，反映了物种与物种、物种与环境之间的关系。这一原理告诉我们，每种生物在生态系统中总占有一定的空间和资源。在恢复和重建退化森林生态系统时，就应考虑各物种在时间、空间和地下根系的生态位分化，尽量使引用的物种在生态位上错开，因为具有相同生态位的种间，必然产生激烈的竞争排斥作用而不利于生物群落的发展和森林生态系统的稳定。在构建人工群落时，可根据各物种生态位的差异，将阔叶植物与针叶植物、耐荫植物与喜阳植物、常绿植物与落叶植物、乔木、灌木和草本植物等进行合理的搭配，以便充分利用系统内光、热、水、气、肥等资源，促进能量的转化，提高群落生产力(何正盛，2003)。

1.3.2.3 生态工程

由于退化生态系统的恢复与重建过程有很大程度的人为促进因素，

并且这个过程是相当综合的和在生态系统层次上进行的，因而在一定意义上，恢复生态与重建也可以看成是复杂的生态工程（岑慧贤和王树功，1999）。西方生态工程理论强调自然生态恢复，强调环境效益和自然调控。中国生态工程则强调人工生态建设，追求经济效益和生态效益的统一和人的主动改造与建设。生态工程是应用生态系统中物种共生与物质循环再生原理，结构与功能协调原则，结合系统最优化方法设计的分层多级利用物质的生产工艺系统，其研究对象不仅是自然或人为构造生态系统，更多的是社会—经济—自然复合生态系统。生态工程是退化生态系统恢复与重建的着眼于生态系统持续发展能力的整合工程和技术。其技术路线着重于恢复生态系统的内部结构和必要功能，并使之具有系统自我维持能力（钦佩等，2002）。

1.3.3 利益相关者理论

1.3.3.1 利益相关者理论的背景

利益相关者理论（stakeholder theory）是20世纪60年代左右，在美国、英国等长期奉行外部控制型公司治理模式的国家中逐步发展起来的。1963年，美国上演了一出名叫“股东”（Shareholder）的戏，斯坦福大学研究小组受此启发，利用另外一个与之对应的词“利益相关者”（Stakeholder）来表示与企业有密切关系的所有人。他们给出的利益相关者的定义是：对企业来说存在这样一些利益群体，如果没有他们的支持，企业就无法生存。这个定义对利益相关者界定的依据是某一群体对于企业的生存是否具有重要影响，显然这种界定方法是从非常狭义的角度来看待利益相关者的（付俊文和赵红，2006）。

进入20世纪80年代以后，随着经济全球化的发展以及企业间竞争的日趋激烈，人们逐渐认识到经济学家早期从“是否影响企业生存”的角度界定利益相关者的方法有很大的局限性。美国的弗里曼（Freeman）对利益相关者理论做了较为详细的研究，他认为“利益相关者是能够影响一个组织目标的实现，或者能够被组织实现目标过程影响的任何个人和群体”（Freeman R E，1984）。这个定义不仅将影响企业目标的个人和群体视为利益相关者，同时还将受企业目标实现过程中所采取的行动影响的个人和群体也看作利益相关者，正式将当地社区、政府部门、环境保护主义者等实体纳入利益相关者管理的研究范畴，大大扩展了利益相关者的内涵（李洋和王辉，2004）。1984年，Freeman在《管理策略》（Strategic Management）上发表了一篇名为《利益相关者探讨》（A Stakeholder Approach）的文章，将利益相关者的概念与理论带到管理领域，

之后，利益相关者的概念广泛深入到各个研究领域。Freeman 的观点受到许多经济学家的赞同，并成为20世纪80年代后期、90年代初期关于利益相关者界定的一个标准范式（贾生华和陈宏辉，2002）。但是 Freeman 界定的是广义上的利益相关者，但这一概念对利益相关者理论的实证研究和实际操作带来极大的局限性，尤其将所有的利益相关者看成一个整体进行研究，将无法得出令人信服的结论（蒋伏心和李家俊，2004）。

到20世纪90年代中期，美国经济学家布莱尔（Blair）把利益相关者定义为："所有那些向企业贡献了专用性资产，以及作为既成结果已经处于风险投资状况的人或集团。"（Blair，1995）布莱尔认为利益相关者是所有那些在公司真正有某种形式的投资并且处于风险之中的人。

可见，利益相关者理论的发展是一个从利益相关者影响（stakeholder influence）到利益相关者参与（stakeholder participation）的过程，得到了众多学科，如管理学、企业伦理学、法学和社会学等学者的关注，启发了各管理部门重视利益相关者的利益诉求，协调他们之间的利益冲突，承担起超越经济目标的更广泛的社会义务和责任。

1.3.3.2　利益相关者及其界定

美国学者米切尔提出了一种"评分法"以界定利益相关者。他认为可以从三个属性对可能的利益相关者进行评分，这三个属性是：合法性，即某一群体是否被赋有或者特定的对于企业的索取权；权力性，即某一群体是否拥有影响企业决策的地位、能力和相应的手段；紧急性，即某一群体的要求能否立即引起企业管理层的关注。根据上述三个特性进行评分，利益相关者可被细分为三类（沈月琴，2005）：

（1）确定的利益相关者。他们同时拥有对企业问题的合法性、权力性和紧急性。为了企业的生存和发展，企业管理层必须十分关注他们的愿望和要求，并设法加以满足。

（2）预期的利益相关者。他们与企业保持较密切的联系，拥有上述三项属性中的两项（顾蕾等，2006）。这种利益相关者又分为以下三种情况：①同时拥有合法性和权力性的群体，他们希望受到管理层的关注，也往往能够达到目的，在有些情况下还会正式地参与到企业决策过程中。②对企业拥有合法性和紧急性的群体，但却没有相应的权力来实施他们的要求，这种群体要想达到目的，需要赢得另外的更强有力的利益相关者的拥护，或者寄希望于管理层的善行。他们通常采取的办法是结盟、参与政治活动、唤醒管理层的良知等。③对企业拥有紧急性和权

力性，但没有合法性的群体。这种人对企业而言是非常危险的，他们常常通过暴力来满足他们的要求。

(3)潜在的利益相关者。是指只拥有合法性、权力性、紧急性三项特性中一项的群体(陈宏辉和贾生华，2004)。只拥有合法性但缺乏权力性和紧急性的群体，随着企业的运作情况而决定是否发挥其利益相关者的作用。只有权力性没有合法性和紧急性的群体，处于一种蛰伏状态(dormant status)，当他们实际使用权力，或者是威胁将要使用这种权力时被激活成一个值得关注的利益相关者。只拥有紧急性，但缺乏合法性和权力性的群体，管理层并不需要、也很少有积极性去关注他们。

1.3.4 公众参与

公众参与(public participation)的思想最早形成于20世纪70年代，美国、法国、加拿大、日本等发达国家对公众参与的研究较早，发展至今已形成了较为完备的体系。公众参与涉及的内容非常广泛，关于其概念和内容，学术界众说纷纭，至今尚未形成统一的认识(万劲波，2003；文同爱和胡春冬，2003)，但分析各概念的内在含义得出：公众通常是指具有共同利益基础、共同的兴趣或者关注某些共同问题的社会大众或群众；参与，指的是建议者和公众共同涉入到项目分析、日程设置和决策的过程，并在主要的问题上达成一致，项目方和公众的地位是平等的，呈现了一种商议的氛围，这是理想状态的参与，也是真正意义上的参与；公众参与就是指具有共同利益、兴趣的社会群体对政府的涉及公共利益事务的决策的介入，或者提出建议的活动(李艳芳，2004)。公众参与反映的是一种基层群众被赋权的过程，目的是要达成社会发展的公正、公平和目标群体收益，界定目标群体，并对其赋予权力如发言权和决策权等，从而有效快速地对目标群体进行动员，使得参与具有积极主动的意识和充分调动公众的潜力，群策群力参与到项目的全过程，不仅锻炼了公众能力，也从中赢得利益(冯文利，2004)。

参与式林业是公众参与在林业中的具体体现，是参与式发展理论和方法运用到森林资源管理中来，可概括为：森林管理的主体是乡村社区群众，将森林的管理看作是乡村社区发展的一个组成部分，社区群众必须积极参与森林经营活动并受益；应当认识到社区和群众在森林管理技术和制度上具备丰富的知识，应当发挥这些知识的潜力，增强他们在森林管理中主人翁的精神；应当进行林地林木权属、税费、利益分配等社会制度方面的改革以密切森林经营和社区群众的利益关系，使他们感到林业既是他们的工作，又是他们本身的利益所在(刘金龙等，1999)。它

与传统林业经营有着本质的区别(陈建成，2002)(见表1-3)。与传统林业思想和经营实践相比，参与式林业的思想和技术是从一个侧面实现森林可持续发展的途径。参与式林业的关键是实现群众参与，需要分析森林与社区和群众生产及生活的联系，重视社区和群众在森林管理中的作用，得到当地群众最广泛、长期、持续的社会支持。这里的群众参与是主动的群众参与过程，群众参与是一个实践性和循环往复的过程，决策采用自上而下的方法。它把作决定的权利交还给社区群众，赋予他们为落实这些决定承担义务和责任。参与式林业的关键问题是"谁参与谁的活动?"，应当是外来支持组织参与到农民的林业活动而不是村民参与外来机构的项目。

欧洲地区环境中心的研究认为，公众参与可以分为三种形式：

(1)民主形式的参与(democratic forms of participation)，指运用民主政治机器如选举、议会、政党等机制进行的参与方式，实际就是政治参与的方式。

(2)非正式形式的参与(informal ways of participation)，指公众独立决定、自发采取的参与方式。

(3)正式形式的参与(formal ways of participation)，指法律规定公众参与所应采取的方式，即公众参与的法律程序和制度。

这三种形式同样可应用到FLR公众参与的形式上，但FLR更侧重于第一种中利用政策机制来促进公众的参与和第二种中公众自发参与的研究。

表1-3 参与式林业与传统林业的比较

参与式林业理论	传统林业理论
以人为中心	以树木为中心
人类与树木是伙伴关系	人类与树木是对立关系
林业管理与其他动植物的管理相联系	林业管理是孤立地进行的
鼓励、提供指导及建议、传授技艺、组织对公众的培训	监督工作
林权多样化	林权比较单一
林业生产的目的以三大效益的综合利用为主	林业生产目的以木材利用为主
多种多样的随时可调整与改变的林业工作发展计划	事先计划好的结构化的林业工作发展计划
建立与公众的联系，公众参与	与公众联系极少，精英决策

促进公众参与是 FLR 概念的核心，作为一个以人为本的方法(Salafsky N 和 Wollenberg E，2000)，FLR 建立在公众参与的基础上，同时，有意义的公众参与也是将景观观点融入决策制定中的关键原则。FLR 中的公众参与，是指不仅要考虑所有利益相关者的需求，也需要他们积极参与决策制定过程，不断的交流、合作、协商，最终建立一个统一的 FLR 方案(IUCN 和 WWF，2005)。

1.3.5　适应性经营

"适应性经营(adaptive management)"一词最早出现于 1978 年，是由各学科生物学家和系统分析学家在描述社会和生物圈的分界面的经营导向原则时提出的(Hartanto H 等，2003)。适应性经营的实施基于两个前提：一是人类对于生态系统的理解是不完全的；二是管理行为的生物物理响应具有很高的不确定性(贾宝全，2001；杨荣金和傅伯杰，2004)，因此它是以可持续经营方式经营巨生态系统的重要方法。

适应性经营是把对自然经济开发作为试验，从中得到经验的实践过程。这个过程本身是直接而简单的，但其中隐含着：新的信息不断被验证、评估时，必须相应调整战略决策和战略目标(Lee K N，1993)。Thomas(2006)指出，适应性经营是人类适应新环境的方法之一，经由不断地学习与体验，让下一次的经营计划能获得更佳结果(Thomas J W，2006)。综合各学者的不同定义(Grumbine R E，1994；Gene Lessard，1998；佟金萍和王慧敏，2006)，适应性经营可以理解为围绕系统经营的不确定性展开的一系列设计、规划、监测、管理资源等行动，是将研究与行动结合在一起的、以学习为导向的方法，目的在于实现系统健康及资源管理的可持续性。在大多数情况下，适应性经营应由规划、经营、监测和评价四个部分组成，四者相互联系、相互作用，以系统的测试假设、达到适应和学习的目的(Salafsky N 等，2001)，同时，计划与实施及监测是一个循环周期的一部分，而不是处于分离、连续的时期 Salafsky N 和 Wollenberg E，2000)。

适应性经营是目前有效处理不确定性问题的管理模式，与传统自然资源经营管理方法的根本区别在于：适应性经营是从试错角度出发，经营管理者随环境变化特别是不确定的影响，不断调整战略来适应管理需要；而传统经营管理方法一般采用行政指令，对不确定问题的考虑甚少，管理滞后现象突出。适应性经营起初只用于渔业和林业，现在已扩展到湿地、水禽、国家公园保护区、恢复工程的经营管理上(Nichols J D 等，1995；Bunch M，2000；Mertsky V J 等 2000；Light S 和 Blann K，

2000)，引起来自生物、经济、生态、教育、心理等众多领域学者的关注和研究兴趣。

1.4 森林景观恢复研究现状

森林景观恢复的兴起与发展首先受到了IUCN、WWF、ITTO、FAO等国际组织的广泛关注(IUCN和WWF，2005；IUCN，2005)。1996年，WWF和IUCN启动“生命之林(forest for life)”项目，提出恢复森林的明确目标——全球森林面积增加，多样性和质量提高，足以在保护生物多样性和维持地球生命的同时，满足人类正常的物质和精神需要，这是FLR的起点(Barrow E等，2002；WWF，2004)。1998年，IUCN对越南、老挝、柬埔寨、泰国的森林恢复活动进行了总结，随之与这四个国家政府的对话，拓宽了有关恢复活动合理性的思想和观念(Gilmour D A，2000)；1999年，WWF和IUCN建立了森林更新计划；2001年，IUCN、WWF及其他一些非政府组织提出了FLR的概念(ITTO和IUCN，2005)。随后围绕森林景观恢复及其技术方法的研究已经成为森林恢复研究的热点领域之一。

ITTO是这一领域的国际倡导者之一。早在1990年就提出了“热带天然林可持续经营指南”(ITTO，1990)，为在国际水平上制定更具体的进行木材生产的热带天然林可持续经营指南提供了国际参考标准。1993年，针对大面积人工林的建立及其产生的环境问题，ITTO推出了“热带人工林建立与可持续经营指南”(ITTO，1993)，而1998年《ITTO热带天然林可持续经营标准与指标》的出版，标志着ITTO在1994年《国际热带木材协议》框架内促进热带天然林保护、经营和可持续发展的工作和活动中取得的进一步进展(ITTO，1998)。2002年，为促进和鼓励热带退化和次生林的经营、恢复、重建和可持续利用，ITTO联合IUCN、FAO、WWF、国际林业研究中心(CIFOR)推出了《热带退化和次生林恢复、经营和重建指南》(ITTO，2002)，弥补了两个已有政策文件《ITTO热带天然林可持续经营指南》和《ITTO热带人工林建立和可持续经营指南》之间的不足。2005年，ITTO与IUCN共同出版了《恢复森林景观——介绍森林景观恢复的艺术与科学》，系统、全面地介绍了森林景观恢复的主要原则和技术，成为连接政策性指导方针和实践的桥梁，目的是帮助森林恢复项目工作人员了解森林景观恢复及其优势(ITTO和IUCN，2005)。

1.4.1 森林景观恢复技术研究

森林景观恢复的概念比较新，但其中的技术却早已存在，并为林业

工作者所熟知。它建立在生态系统途径和生态系统经营的基础上(Schlaepfer R，2005)，融合了利益相关者方法、适应性经营、参与式方法和其他新技术，为森林可持续经营和生态系统恢复提供了一个补充框架。在森林景观恢复正式得到定义以前，Radeloff V C 等(1998)就分析了威斯康辛州西北部实施森林景观恢复的潜力。《Forest Restoration in Landscapes：Beyond Planting Trees》一书从概念、目标、面临的挑战、政策干预和参与式方法的应用等方面详细阐述了森林景观恢复(Mansourian S 等，2005)。Aldrich M 等(2005)在 IUCN 与 WWF 出版的森林保护简报《Arborvitae》中，简单介绍了森林景观恢复。Lamb D 等(2005)在《Science》上发表《恢复退化热带森林景观》，指出阻止森林退化和提高居民福利的森林景观恢复是改善热带森林景观的有效途径。Rietbergen-McCracken J 等(2007)在 ITTO 和 IUCN 联合出版的《恢复森林景观：森林景观恢复的艺术与科学介绍》的基础上编写的《森林景观恢复手册》则为实地实施森林景观恢复提供了可操作指南。

除以上对森林景观恢复进行全方位的评述与研究(Dudley M，2005)外，许多学者也分别在适应性经营、公众参与、森林景观动态、优先恢复立地的选择、退化原始林恢复技术等方面进行了相关研究(张晓红等，2007)。

1.4.1.1 利益相关者决策分析法

在森林景观恢复倡议初期就要确定主要的利益相关者，然后在恢复过程中逐渐修改，最初确定的关键利益团体有可能在恢复活动后期成为相关性小的群体。Marghescu T(2001)认为实施森林景观恢复首先要考虑所有利益相关者的需求，尤其是当地居民的需求，同时也需要他们积极参与决策制定过程，不断地交流、合作、协商(Ravnborg H M 和 Westermann O，2002)，确定技术上最合适的、社会经济可接受的恢复选择，平衡土地利用折衷(land-use trade-offs)，最终制定一个统一的 FLR 规划(IUCN 和 WWF，2005)。Dubois O(1998)提出了帮助利益相关者协商并联合制定决策的“4R”框架，即列出利益相关者的权利、责任、效益和关系，Colfer C 等(1999)介绍了印度尼西亚使用此框架的案例，并认为“4R”框架是合作式森林经营项目中不同利益相关团体行动学习过程必备的工具。Braakman L 和 Edwards K(2002)在促进利益相关者协商决策时应用了头脑风暴的工具。Koontz 和 Bodine(2008)在多年研究美国林业经营的基础上，认为利益相关者的识别、调查和合作能有效促进政府部门对林业、土地等自然资源的管理。

1.4.1.2 景观镶嵌体与景观动态分析

实施森林景观恢复以前，要充分理解森林景观镶嵌体及其动态变化，并进一步分析变化的动因(Lamb D，2003；ITTO 和 IUCN，2005)。许多学者分别以玻利维亚(Pacheco P 和 Mertens B，2004)、科特迪瓦(Barima Y S S，2009)、美国(Riitters 等，2009)、巴西(Teixeira，2009)、澳大利亚(Stork N E 和 Turton S，2008)的森林为例，分析了不同研究区的森林景观镶嵌体和景观动态变化。此外，Bennett A(1999)重点讨论了景观镶嵌体中廊道的功能，Zhou 等(2008)分析了岷江上游实施森林景观恢复前后的植被动态。Wightman C S 和 Germaine S S(2006)分析了美国西南部森林恢复前后的林分特征。景观动态模拟是景观格局分析的重要手段，Xi W M 等(2009)综述了森林景观恢复可能用到的森林景观模型的类型、方法、发展和应用(Xi W M，2008)，Teixeira(2009)对巴西大西洋热带雨林 1962 ~ 2000 年的变化进行了模拟，并预测了 2019 年的景观格局，对比了研究时段的毁林和森林恢复速度。Peng S L 等(2010)通过建立 Markov 模型，预测了中国亚热带森林的演替过程，用以指导森林恢复活动。驱动力分析也是理解景观动态变化的研究热点，Bradstock R A(2008)和 Long J N(2009)分析了限制森林生态系统恢复的自然驱动因子，如火灾等。

1.4.1.3 立地水平恢复技术

森林景观恢复立地水平的技术包括：退化原始林的改造和能动经营；次生林生长量的能动经营；退化林地主要森林功能的重建；退化林地和边缘农业用地上天然更新的促进；生态恢复；造林和人工林；混农林业和其他农林结构(configurations of on-farm trees)。任何森林景观恢复倡议可以包括以上一条或多条。在立地水平上，各种恢复措施可以在很多地点实施，从严重退化的立地(例如采矿区)到只受到轻微干扰、只需保护就能自然恢复的立地(Hobbs 和 Morton，1999)。优先恢复的立地选择取决于恢复的主要目标，也有许多选择原则和技术。Orsi F 等(2010)以墨西哥 Chiapas 为例通过空间多尺度分析，首先以恢复地区的总面积和适合恢复的最小尺度为参数，生成多个恢复选择，再引入生态和社会经济指标评价每个恢复选择的保护生物多样性和提高社区福利的能力，最后利用敏感性分析测试评价结果，进行了确定优先恢复立地的研究。针对不同退化状态的森林和林地，退化原始林恢复的基本原则是利用自然动态过程经营退化原始林分，恢复策略取决于林分条件、恢复项目的目标、资源的可用性，有时也应采取必要的人工辅助更新措施

(Saunders 和 Norton，2001；Shono K，2007)。次生林的两个主要经营策略是：经营改良的休耕地而不降低农业生产力和为生产和保护目的而经营森林(Smith J，2001；Ugarte J，2004；Saynes V 等，2005；Dent 和 Wright，2009)。Clewell F A(1999)探讨了美国佛罗里达采矿地河岸带的恢复技术，Stanturf J A 等(2007)提出了受飓风影响的森林恢复策略，Egan D(2007)研究了美国西部老龄林的恢复措施，Chazdo R L(2008)从森林服务功能角度提出退化林地恢复策略，Kobayashi S(2007)利用人工造林重建退化林地、恢复热带森林景观，Santiago-Garcia R J (2008)研究了保育木在热带森林恢复中的作用，Omeja P A(2009)对比了补植和天然更新在恢复中的作用，指出恢复弃耕多年的农地的森林功能，人工辅助天然更新的恢复效果更好。以上研究所包括的具体恢复措施主要体现为：以重建立地条件的恢复措施和以提高生物多样性为目的的干预措施。具体应用时，可以选择多种恢复措施，以提高整个景观的生态完整性。Maginnis S 等(2003)分析了人工林在森林景观恢复中的作用，Dostálek J 等(2007)评价了不同造林技术在恢复农业用地森林功能中的效果。

1.4.1.4　适应性经营

适应性经营是实施森林景观恢复必须遵循的原则之一，它是将研究与行动结合在一起的、以学习为导向的方法，准确地讲，它是计划、经营和监测的综合，以系统的测试假设、达到适应和学习的目的(Salafsky N，2001；Jacobson C，2003)。适应性经营起初只用于渔业和林业，现在已扩展到湿地、水禽、国家公园保护区、恢复工程的经营管理上(Nichols J D，1995；Bunch M，2000；Mertsky V J，2000；MacDonald G B 和 Rice J A，2004；Schmiegelow F K A 等，2006；Smith G K M，2008)。ITTO 恢复指南(2002)指出，退化与次生森林的恢复、经营和重建策略必须采用长期的观点，尽可能的预测未来发展方向，同时又必须是灵活的，以适应环境的变化(ITTO，2002)。森林景观恢复中的适应性经营不仅考虑生态因素(Berkes F，2000；Bakker V J 和 Doak D F，2009)，还要考虑社会、经济、制度因素(Berkes F，2009；Duckert D R，2009；Stankey G H，2003)。Fernandez-Gimenez M E(2008)以美国西部 5 个社区林业组织为例，详细阐述了森林恢复与适应性经营中社会学习和社区合作的重要作用。Leskinen P(2009)等分别研究了适应性经营方法在森林模拟、森林经营方案中的决策分析、景观尺度生物多样性保护和跨边界景观经营等方面的应用(Yousefpour R 和 Hanewinkel M, 2009；Leskinen P，2009；Cassano C R，2009；Gass R，2009）。Prato T（2009）则阐述了模糊理论在适应性经营中的作用。

1.4.1.5 公众参与

促进公众参与是森林景观恢复概念的核心，作为一个以人为本的方法（Salafsky N 和 Wollenberg E，2000），森林景观恢复建立在公众参与的基础上，同时，有意义的公众参与也是将景观观点融入决策制定的关键原则。森林景观恢复中的公众参与，是指不仅要考虑所有利益相关者的需求，也需要他们积极参与决策制定过程（Bouthillier P L 和 Roberge A，2007）。ITTO 认为森林景观恢复中应用权益相关者决策分析法应注意以下几点：保证所有利益相关者参与到行动学习中，参加森林景观恢复活动的利益团体代表必须是团体成员选举的，团体代表必须与成员协商后才能做出决定；支持利益相关者建立经验；接纳利益相关者的所有需要；建立平等的交流机会（ITTO 和 IUCN，2005）。在森林景观恢复正式定义前，Rauscher（1999）对公众参与美国联邦林业决策的进展进行了综述，为后来的公众参与森林景观恢复各项具体恢复措施的制定提供了借鉴。Linkov I（2006）在分析风险评估、多标准决策分析和适应性经营的发展和应用时，指出公众参与程度是评价这些方法的重要指标。从参与式方法在森林景观恢复中的应用来看，公众参与重点体现在景观制图（Kalibo 和 Medley，2007）、景观动态变化分析（Castella J C 等，2005）、参与式调查（Rayburn A P 和 Schulte L A，2009）、立地水平恢复措施的制定（Shindler B，1996；Chazdon R L，2008）、监测与评价（Johnson N L，2003；Reynolds K M，2005）等方面，如 Thomas D S 等（2006）在美国西南部黄松（*Pinus ponderosa*）的生态系统恢复项目中，采用参与式方法协调不同利益相关者之间的冲突，最终达成一致的恢复目标。Espiritu N O 等（2007）应用一套可操作的、可测量的森林可持续经营标准与指标评价了森林景观恢复倡议中基于社区参与的森林经营项目的进展。

1.4.2 森林景观恢复应用研究

森林景观恢复在国家尺度的应用始于 1985 年坦桑尼亚希尼安加地区 *ngitili*（对当地居民的生计起重要作用的林地）的恢复，经过 15 年的努力，2000 年该地区恢复了 35 万 hm^2 的森林，基本实现了森林景观的恢复，居民福利在人均收入、林产品产值等方面得到显著提高（Barrow E 等，2002）。尽管坦桑尼亚的森林恢复最初是在土壤保护方面开始实施，并非景观恢复方面，但之后从传统的林业活动转为更广的恢复林产品和服务方面，这就与森林景观恢复的目标相一致（Monela G C 等，

2005)。与此同时，肯尼亚、乌干达、越南、老挝、柬埔寨、泰国也开始了退化森林景观的重建工作(Gilmour D A 等，2000)。

在 IUCN、WWF、ITTO、FAO 等国际组织的推动下，许多国家和地区正在采取积极措施开展森林景观恢复工作，并出现了许多森林景观恢复成功案例(IUCN 和 WWF，2005；Thomas P T，2005)。WWF 支持下的 5 个生态区森林景观恢复案例：保加利亚的恢复稀有鸟类栖息地天然林、中国的恢复大熊猫栖息地景观、马来群岛的建立野生动物迁徙廊道、巴西的保护大西洋片断森林并恢复其中的连通性、新喀里多尼亚的保护热带干旱森林顺利开展(Ecott T，2002)；尼泊尔通过人工促进天然更新等措施恢复了中部丘陵地区的森林景观(Lamb D，2003)；印度尼西亚建立了混农林业体系，为当地农户提供经济收入来源，也促进了采伐迹地的生物多样性恢复；中欧和北欧地区的芬兰西部、俄罗斯中部、苏格兰地区也开展了森林景观恢复案例实施(Veltheim T，2005；IUCN，2006)。

自 2005 年 4 月在巴西彼得罗波利斯举办森林景观恢复实施研讨会后，森林景观恢复的实践得到了迅速发展。会后发布的《彼得罗波利斯宣言》列举了利用森林景观恢复途径在退化或砍伐的林地中，对重要的生态系统产品和服务功能进行恢复，从而改善人类生计的成功经验，包括坦桑尼亚、英国、巴西、中国、印度、马里等国家的森林恢复情况。IUCN 与 WWF 出版的森林保护简报《Arborvitae》，列举了世界所开展的一系列实例，包括坦桑尼亚 ngitili(对当地居民的生计起重要作用的林地)的恢复、印度红树林湿地的恢复、联合王国政府发起的恢复古代林地的运动；同时还列举了在 WWF 支持下建立的恢复活动，如 2004 年启动的恢复秘鲁神庙附近退化流域的项目、葡萄牙栓皮栎林景观恢复项目等(IUCN 和 WWF，2005)。与此同时，在 2002 年 ITTO 出版的《热带退化与次生森林恢复、重建和经营指南》(ITTO，2002)的基础上，ITTO 和 IUCN 在 2005 年联合出版了《森林景观恢复手册》，详细阐述了森林景观恢复的主要原则和技术，成为连接政策性指导方针和实践的桥梁，目的是帮助森林恢复项目工作人员了解森林景观恢复手册及其优势，并付诸实践(ITTO，2005)。

分析不同地区的森林景观恢复案例，可以得出森林景观恢复成功的经验：制定实际、全面的目标；保证当地居民参与恢复项目的全过程；所有规则的制定是为了满足社区需求，而不是政府需求；政府的推动与支持；要承认恢复并不能替代预防森林退化，也不能完全恢复森林所有

的功能价值；在自然恢复和人为恢复之间作出正确的选择；在立地水平的经营活动中考虑景观水平的目标，不仅能建立健康的森林景观，也能促进立地水平的经营活动。经验表明，由于条件差异性、所用途径和方法多样性、所用工具广泛性的特点，成功的森林景观恢复并无蓝图，皆为因地制宜。是自下而上的过程，来自生活在这些土地上的人们和受到景观直接影响的利益相关者。同时，森林景观恢复实施起来非常困难，通常面临 3 个障碍：利益相关者及其利益的明确、优先立地的确定和适当的激励机制和补偿机制。最主要的成功因素是促进公众参与（从地方执行人员到与森林有关的国际组织和政策进程），尤其是当地居民的参与。政府的推动也是森林景观恢复成功的关键因素，应尽快将森林景观恢复纳入国家林业政策中。

1.4.3 森林景观恢复全球伙伴关系

早在 1996 年 WWF 和 IUCN 发起的“生命之林”项目中，就提出了建立国际组织和政府机构的全球伙伴关系。森林景观恢复正式定义前，全球伙伴关系的工作重点是促进实地经验的交流和政策对话。森林景观恢复概念提出后，为将森林景观恢复的思想落实为行动，必须采取有力的执行方式，形成力求取得成果的文化。为此，应当使政府间行动同地方和区域二级的具体行动挂钩——明确地将政策同实践挂钩——并使主要行为者共同交换建设性意见并查明各种可能性。为应付这项挑战，IUCN、WWF 和大不列颠森林委员会于 2003 年 3 月在罗马发起了森林景观恢复全球伙伴关系，提供了一个在全世界范围内分享经验和相互学习的工具。其持续不断追求的目标是促进和加强有利于当地社区和自然、并有助于履行保护森林的国际承诺的各种恢复森林景观范例的网络（Dudley M，2005）。

有关伙伴包括英国、肯尼亚、芬兰、美国、日本、萨尔瓦多、意大利、瑞士和南非等国政府，加纳森林研究所，国际林业研究中心（林业中心），IUCN，WWF，ITTO，环境规划署世界养护监测中心，联合国森林论坛秘书处，世界农林中心，生物多样性公约秘书处，宗教和养护联盟和国际四方援助救济社。中国也于 2008 年加入伙伴关系。若干其他政府、组织和公司正在采取步骤加入这种伙伴关系（IUCN 和 WWF，2005）。

2005 年 4 月 4 ~ 8 日，来自世界各地的 100 多名代表参加了在巴西彼得罗波利斯市举行的“森林景观恢复实施研讨会（Forest Landscape Restoration Implementation Workshop）”。代表们呼吁国际社会应更广泛

地利用森林景观恢复途径来更好地保护森林及其生物多样性，防治荒漠化，促进联合国千年发展目标的实现。会后发布的《彼得罗波利斯宣言》呼吁更多的成员加入“森林景观恢复全球合作伙伴计划”；并呼吁国际社会积极采取行动恢复森林景观，造福于人类和自然界，扭转森林丧失和退化的趋势。

现在全球伙伴关系已在巴西、中国、哥伦比亚、巴基斯坦、泰国、加纳和越南等国以及肯尼亚/乌干达埃尔贡山，地中海，中欧和北欧，西非、东非、中部非洲和北非，东南亚，中美洲和南美洲等子区域或区域举办了研讨会（Veltheim T 等，2005；IUCN，2005；Barrow E 等，2002；Ecott T，2002）。

1.4.4 森林景观恢复在中国的发展

在国际社会日益重视森林景观恢复的同时，我国也开始了森林景观恢复的研究工作。2004 年，“中国森林景观恢复研讨会”在四川省举行——这是我国首次就森林景观恢复（FLR）问题举办的专项研讨；2005 年 4 月江泽慧代表国家林业局参加了巴西森林景观恢复国际研讨会，并发表《中国退化土地与退化森林生态景观恢复》的演讲（江泽慧，2005）；2008 年 3 月，中国加入了森林景观恢复全球伙伴关系（The Global Partnership on FLR）。目前，由 WWF 资助、在四川省岷山实施的旨在恢复大熊猫栖息地景观的项目已成功结题，由 ITTO 推动的“ITTO 森林景观恢复手册在中国热带地区的示范培训、应用与推广”项目和作为 IUCN“生计与景观”项目之一的“森林景观恢复与改善林业社区生计”项目正在顺利开展。

森林景观恢复也同样得到了我国学者的关注，如贾乐思在《森林景观恢复概要》中介绍了 WWF 出版的《景观水平上的森林恢复：仅仅种树是不够的》中的主要内容（贾乐思，2006），楼新盼（2003）在《森林景观的恢复》中总结了实施森林景观恢复的重要性等（张晓红等，2007）。尽管我国对于森林景观恢复理论与方法的研究处于翻译、介绍的阶段，但是在景观生态学、恢复生态学、参与式林业、监测与评价等方面进行了大量研究（臧润国，1998；彭少麟，1999；彭镇华，1999；郭晋平等，2000；任海等，2001；包维楷，2001；郭晋平和张芸香，2002；郭晓敏等，2002；何正盛，2003；李秀珍等，2004；），为我国森林景观恢复研究提供了坚实的理论与技术方法研究基础。

早在 20 世纪 50 年代我国就开始了退化环境的长期定位观测试验和综合整治工作。50 年代末华南地区退化坡地上开展的荒山绿化、植被

恢复，70 年代三北地区的防护林工程建设(田亚平，2004)，80 年代长江中上游地区(包括岷江上游)的防护林工程建设、水土流失工程治理等一系列的生态恢复工程，使我国的生态环境不断改善(包维楷和陈庆桓，1999；包维楷等，2001)。从 1980 年开始在退化或脆弱生态环境进行森林恢复和重建的工作，提出了许多切实可行的生态恢复与重建技术与模式(何正盛等，2003)，先后发表了大量的有关生态系统退化和人工恢复重建的论文、报告和论著。如余作岳(1990，1997)等对热带亚热带退化生态系统植被恢复与重建过程中群落结构、建群植物生理生态特性、生境变化、能量吸收与转化、养分循环、土壤肥力、动物与微生物群落变化等方面开展了深入研究，提出退化生态系统恢复可分三步走，即重建先锋群落、配置多层次多种乡土树种的阔叶林和重建复合农林业生态系统(余作岳，1990；余作岳和彭少麟，1997；孙书存和包维楷；2005)；喻理飞(1991)、刘庆(2002)、王国梁(2002)等分别对退化喀斯特、岷江上游亚高山稀疏天然林、黄土高原丘陵壑区、风灾迹地、退耕地(侯扶江等，2002)及退化荒山(王国梁等，2002)进行了退化生态系统森林植被恢复与重建模式等方面的研究(李先琨和黄玉清，1997；郭晓敏等，2002；刘建军等，2002；任海和彭少麟，2002；张劲峰等，2005)；温远光、彭少麟(1999)、包维楷(2000)等针对亚热带常绿阔叶林开展了生态恢复研究(包维楷和陈庆恒，1999；赵平等，2000)；江泽慧和彭镇华等(1999)提出了我国不同地区的植被恢复模式。以上研究为我国的森林景观恢复研究提供了坚实的理论与技术方法研究基础。

由于我国的森林景观恢复工作起步较晚，面对森林退化、破碎化和修正化导致的森林景观生态功能下降和居民福利下降的挑战，我国学者需要在不断研究对国外森林景观恢复的成功案例、吸取并借鉴先进的景观恢复技术的基础上，通过整合现有的景观生态、森林恢复、社区林业等研究成果，来指导我国森林景观恢复工作不断向前发展。

第二章　研究区概况和研究方法

2.1　陵水黎族自治县概况

2.1.1　地理位置

海南省陵水黎族自治县位于海南岛的东南部，地处北纬 18°22′ ~ 18°47′，东经 109°45′ ~110°08′。东南濒临南海，东北部与万宁市交界，北部与琼中黎族苗族自治县相连，西部与保亭黎族苗族自治县接壤，西南与三亚市毗邻(如图 2-1 所示)。全县南北长 40km，东西宽 32km，海岸线长 57.5km。全县陆地总面积是 $1128km^2$，水域 $79km^2$。海榆公路和东线高速公路横穿全境，县城距省府驻地海口市 196km，距三亚市 80km。

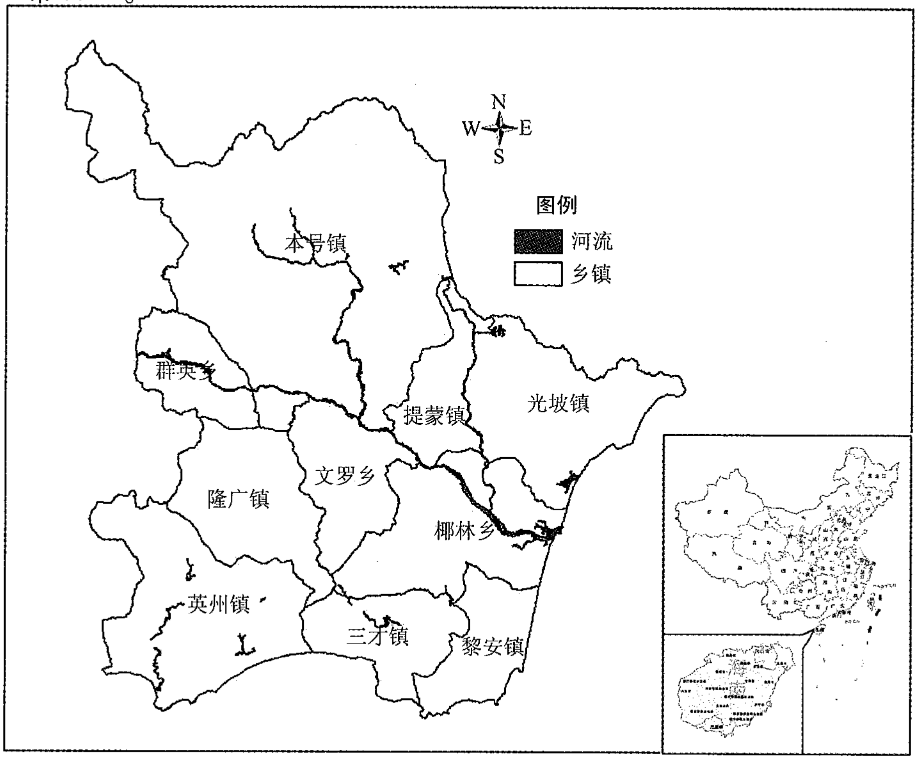

图 2-1　陵水黎族自治县位置图与行政区划图

2.1.2 气候特征

陵水黎族自治县地处低纬度、属热带季风岛屿性气候。光热资源充足，常年平均气温在24.7℃左右，1月份平均最低气温为19.8℃，7月平均最高气温30℃，历年最高气温为37℃，历年最低气温为5.6℃，常年积温平均值为9050.1℃。年平均降水量为1500～2500mm，全年旱雨季节分明，每年11月份至次年的4月份为旱季，5至10月为雨季，雨季降水量占全年降水量85%以上。季风明显，夏半年盛行西南季风，冬半年盛行东北季风，平均每年受3～5次台风的袭击，最大风力达12级，风速40m/s。

2.1.3 地质地貌

根据地层发育、沉积建造、岩相及生物组合等构造运动特征，海南岛可划分为海口、五指山、三亚三个地层分区。陵水黎族自治县位于三亚地层分区内，浅层地质结构简单，成土母岩、母质花岗岩占86.2%，砂页岩占0.5%，河流冲击物占2.3%，浅海沉积物占6.7%，北部山地的成土母岩为云母岩和石英正长岩；西部丘陵母岩为石英斑岩和花岗岩闪长岩；中部为混合岩；东南部沿海平原为浅海沉积物和混合岩；砂页岩主要分布在南部的文建岭、南湾半岛和北部的香水湾一带。

表2-1 陵水黎族自治县地貌类型统计表

地貌类型		面积(km^2)		占土地总面积(%)
低山	海拔800～1499m	199.2	155.2	17.66
	海拔500～800m		44.0	
丘陵	海拔250～500m	243.4	153.8	21.58
	海拔100～250m		89.6	
台地	台面	371.3	226.7	32.91
	台坎		144.6	
平原	海积平原	181.5	139.6	16.09
	半固定沙丘		17.5	
	未固定沙丘		24.4	
河谷阶地		95.8	95.8	8.49
泻　湖		36.9	36.9	3.27
土地总面积		1128	1128	100

地势走向西高东低，地貌类型及面积见表2-1。北部为山地，最高峰为吊罗山山脉三角山，海拔1499.8m。海拔800m以上的有吊罗山、大吊罗山和三角山、香蕉岭、吊罗岭。丘陵地区分布于西部，包括群英乡、祖关镇、田仔乡的全部，军田乡、本号镇、英州镇、文罗镇、隆广

镇的一部分。境内东北部西南走向的吊罗山脉与西北部东南走向的七指岭山脉呈“八”字形相交于县城西北部，将东部浅海沉积平原团团包围，形成海南岛著名的“陵水盆地”，盆地内部零星分布着两大山脉及余脉延伸形成的弧丘和台地。境内河流下游与沿海地区均为平原地带。

2.1.4　土壤特征

陵水黎族自治县的地层基质由古老的砂页岩衰质岩系、中生代浆岩、沿海第四系松散层以及河流冲击地层构成。全县土壤基本上划分为4个土类、14个亚类、28个土属(见表2-2)。花岗岩山地黄壤主要分布在北部海拔750m以上的山地，花岗岩砖红壤性红壤，主要分布在海拔450 ~750m的山地，花岗岩红壤主要分布在海拔450m以下的丘陵、台地，滨海沙土属于滨海平原。

表2-2　陵水黎族自治县土壤类型统计表

土类	面积(hm^2)	亚类	土属
山地黄壤	15517.45	黄壤、黄泥土、粗骨性黄壤	花岗岩灰化黄壤、酸性岩粗骨性黄壤
赤红壤	4397.73	暗色赤红壤	花岗岩暗色赤红壤
砖红壤	47399.21	水化红壤 暗褐色赤红壤	花岗岩暗褐色砖红壤 粗骨性红壤、红赤土地、黄赤土地
水稻土	20431.71	潜育性水稻土	冷底田、青底泥田
		渗育性水稻土	白缮泥田、滨海沙积田
		潴育性水稻土	黄赤水田、潮沙泥土、泥肉田、潮沙泥田
		沼泽性水稻土	泥炭水田、渍冰田、烂碰田
		盐渍性水稻土	咸田、咸酸田

2.1.5　水文水系

陵水黎族自治县境内河流纵横交错，大小河共有150多条，流量大，落差高，主要河流陵水河、英州河和港坡河都经过本区汇入南海，区内另有四条小溪独流入海。其中陵水河为最大河流，年平均流量9.3亿m^3，集雨面积1210.7km^2，主要干流发源于保亭黎族苗族自治县的娥隆岭，支流发源于吊罗山，全长75.7km。主要水库有小妹水库、走装水库、黎跃水库和小南平水库。地表多年平均径流1216mm，年径流总量13.16亿m^3，全县平均每人有水量5576m^3，水资源比较丰富。地下水主要是浅层地下水，基本上没有承压地下水。

2.1.6 植被特征

由于气候的立体分异，陵水黎族自治县自然植被具有垂直分布规律。林地和未利用土地是自然植被分布的两大地类，占地面积896075.8亩，占土地总面积的53.4%。

自然植被类型有高山矮林、针阔混交林、常绿落叶混交林、次生林和人工林。高山矮林分布于海拔1000m以上的吊罗山区，由于土层瘦瘠，山高风大，树木生长受到限制，林木一般高5 ~8m，代表植物有高山的了哥、大头茶、米锥和高山苦竹等，林下常有10多cm的苔藓植物。针阔混交林分布于海拔600 ~1000m的山腰山腹，树木高大，代表植物有陆均松、坡垒、母生、油丹等，林下有喜阴聚类和藤本植物。常绿落叶混交林分布于东北部靠海的牛岭山地，由于近海山低，森林遭受人为破坏严重，海拔300m以下林木地已为灌木林和其他疏林、次生林替代，代表植物有青皮、红罗、加卜、海南锥栗等。次生林分布在400 ~600m的西部山地，包括大敢岭至廖次岭一带，原始森林砍伐殆尽，被灌木丛和荒草地替代。人工林分布在东南沿海沙滩和丘陵坡麓的荒坡沙砾地，原生植被为刺灌丛，耐旱植物仙人掌。经造林改造，主要树种有木麻黄(*Casuarina equisetifolia*)、隆缘桉(*Eucalyptus emserta*)、苦楝(*Melia azedarach*)、台湾相思(*Acacia confusa*)及热带树种母生(*Homalium hainanense*)、樟木(*Cinnamomum Parthenoxylon*)、花梨、柚木(*Tectona grandis*)等。

2.1.7 自然资源

(1)森林资源：林业资源非常丰富，林地后备资源有很大的开发潜力。据2005年抽样调查，全县林业用地面积6.80万hm^2，有林地面积6.22万hm^2，森林蓄积量602万m^3，森林覆盖率57.2%。树种繁多，有3500多种，珍贵树种有：青皮(*Vatica mangachapoi*)(国家重点保护林木)、红绸(*Lithocarpus fenzelianus*)、黑稠、油丹(*Alseodaphne hainanensis*)、毛丹(*Phoebe hungmaoensis*)、母生、坡垒、花梨、绿楠(*Manglietia hainanensis*)、子京(*Madhuca hainanensis*)、短叶罗汉松(*Podocarpus macrophylla*)、竹柏(*Podocarpus nagi*)、海南油杉(*Keteleeria hainanensis*)、青梅(*Vatica mangachapoi*)、枇杷丹、海棠、红桐、黑洞、石梓(*Gmelina arborea*)等。

(2)水力资源：水资源相对较丰，人均淡水拥有量5199m^3。北部降雨量较大，南部地下水丰富，储量达2.9亿m^3。全县水资源总量为16亿m^3，占全省的5%。省内第四大河流——陵水河总长76km，年均流

量13.16亿m^3。全县大小河流共有150多条，水利设施较好，共修建大、中、小型水利工程83宗。其中水库工程67宗，引水工程16宗。另外还有提水工程39宗。水库总库容量1.9亿m^3。

(3)海洋资源：陵水黎族自治县海域总面积为1223km^2，系指东北至西南一带的南海和内海港湾，东北起点分界洲，东南土福湾。海岸线全长57.5km，东北部与万宁市海域交界，以分界洲为界，东南部与三亚海域交界。沿海的东部和南部各有一处特别折入陆地，分别形成了黎安港、新村港。此外还有香水湾、土福湾、山牛港、水口港、赤岭湾和清水湾等港湾。陵水黎族自治县东南至东北面临浩瀚的南海，矿产资源丰富，宽阔的海岸滩涂有钛、锆、锡、铅、石英砂、高岭土、花岗岩等。钛储藏量200万t，石英砂储藏量1亿t，高岭土储藏量600万t，陵水盐场每年生产原盐2000t。海洋鱼类资源十分丰富，品种较多，据资料记载有700多种，其中具有较高经济价值的鱼类有40多种。港湾水温、盐度适宜，海水比重稳定，浮游生物丰富，是养殖珍珠、石斑鱼、对虾、贝类、藻类的优质天然养殖场。

(4)热作瓜菜资源：陵水素有“天然温室”、“热作种植宝地”之美称，是我国最早的南繁育种基地，是海南冬季瓜菜生产、海水养殖珍珠主要基地之一。这里盛产椰子、槟榔、荔枝、龙眼、杨桃、火龙果、圣女果、香蕉、杧果、胡椒、灯笼辣椒、西瓜、香瓜等经济瓜果。

2.1.8 社会经济状况

陵水黎族自治县现有1个镇7个乡，114个行政村，611个自然村，88375户。境内还有省属国营南平农场、岭门农场和吊罗山林业局三个国有机构。2009年全县总人口36.4万人，农业人口占73.8%，全县有黎、汉、苗、壮族等16个民族，其中汉族人口占44.8%，其他少数民族人口占55.2%，是黎、汉、苗等民族小聚居、大杂居的县份。方言主要有汉语(海南话)、黎语和苗语，海南话是境内的主要语言。2009年，国民生产总值为38.1亿元，其中第一、二、三产业产值分别为19.1亿元、7.5亿元、11.5亿元，产业结构比为50.2∶19.6∶30.2。

2.2 大敢森林景观恢复示范区概况

大敢FLR示范区位于海南省陵水黎族自治县西北部的群英乡大敢村，地处北纬18°34′35″，东经109°51′05″，海拔30～340 m，面积约400 hm^2。地貌以丘陵为主，土壤以棕色黄壤为主。森林资源丰富，有降香黄檀(*Dalbergia odorifera*)、无翼坡垒(*Hopea exalata*)、青皮(*Vatica* *mangachapoi*)和野生荔枝(*Litchi chinensis*)等珍贵乡土树种和水石梓(*Sarcosperma laurinum*)、海南红豆(*Ormosia pinnata*)、万宁柯(*Lithocarpus elmerrillii*)、猫尾木(*Dolichandrone cauda-felina*)、丛花厚壳桂(*Cryptocarya densiflora*)、黄杞(*Engelhardtia roxburghiana*)、海南哥纳香(*Goniothalamus howii*)等海南常见树种。

大敢村属典型的黎族聚居区，分为芬优、芬界和大干三个村民小组。2009 年全村共有 134 户、586 人(皆为黎族)，男 348 人、女 259 人，其中劳动力 414 人。出售橡胶、槟榔是主要收入来源，2009 年人均纯收入 750 元左右。

2.3 研究方法

2.3.1 遥感数据获取与处理

收集研究区多期遥感影像，从 1∶10000 地形图上选取明显地物点作为控制点对所有影像进行校正，对校正后的影像进行融合处理。采用自动分类和目视解译相结合的方法进行信息提取，首先通过自动分类，解译出水域、植被、裸地等类型，再根据研究区基于 FLR 的景观要素分类系统，参考研究区同时期一类调查和二类调查数据，结合地面调查，建立解译标志，完成目视解译，划分出最后的图斑。通过精度评价和小图斑聚类分析等分类后处理，得出不同时期的景观镶嵌图。信息提取流程如图 2-2(详见第四章)。

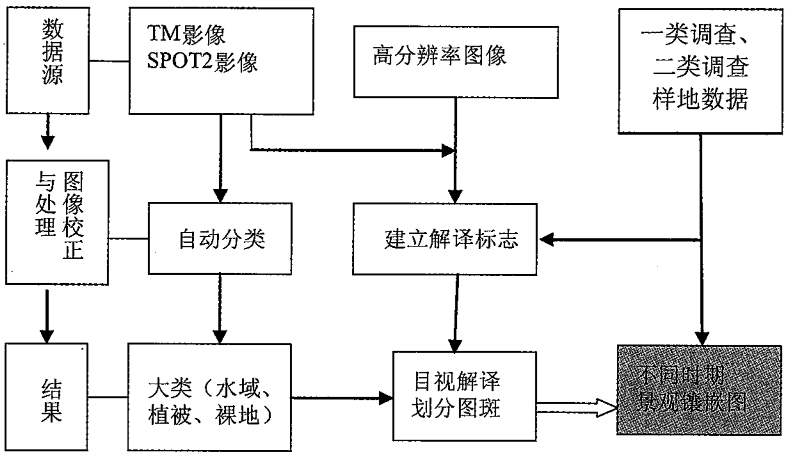

图 2-2 遥感信息提取流程图

2.3.2 景观指数方法

景观指数是指能够高度浓缩景观格局信息，反映其结构组成和空间配置某些特征的简单定量指标。景观格局特征可以在3个层次上分析：单个斑块(individual patch)，由若干单个斑块组成的斑块类型(patch type或class)，以及包括若干斑块类型的整个景观镶嵌体(landscape mosaic)。因此，景观格局指数亦可相应地分为斑块水平指数、斑块类型水平指数以及景观水平指数。目前用于刻画景观格局的指数很多，但是大多数指数间呈现极高的相关性，因而说服力不强(李秀珍等，2004；王新明等，2006；林孟龙等，2008)，实际应用中选用具有代表性的指数即可完全满足格局分析的需要，反映研究区景观格局的特点(王景伟和王海泽，2006)。

针对研究区的特点和研究目的，本书以ArcView GIS 3.3的扩展模块Patch analysis为工具，选取具有较高独立性、良好灵敏度、能充分反映生态学意义的代表性景观指数(陈文波等，2002；布仁仓等，2005；何鹏等，2009)，包括类斑面积(CA)、面积比(PLAND)、斑块数(NP)、斑块密度(PD)、平均斑块面积(MPS)、边缘密度(ED)、平均斑块形状指数(MSI)，景观多样性指数SDI、均匀度指数SEI和优势度指数D。各指数的计算公式和生态学意义如下(邬建国，2000；郭晋平和周志翔，2007)：

(1)类斑面积(CA)，单位：hm^2，范围：CA>0

$$A_i = \sum_{j=1}^{N_i} A_{ij} \tag{2.1}$$

式中：N_i为第i类景观要素的斑块总数(下同)，A_{ij}为第i类景观要素第j个斑块的面积。

生态意义：CA度量的是景观的组分，也是计算其它指标的基础。它有很重要的生态意义，其值的大小制约着以此类型斑块作为聚居地(habitation)的物种的丰度、数量、食物链及其次生种的繁殖等，如许多生物对其聚居地最小面积的需求是其生存的条件之一；不同类型面积的大小能够反映出其间物种、能量和养分等信息流的差异，一般来说，一个斑块中能量和矿物养分的总量与其面积成正比。

(2)斑块所占景观面积的比例(%PLAND)，单位：百分比，范围：$0 < \%PLAND \leq 100$

$$\%PLAND = \frac{A_i}{A} \times 100 \tag{2.2}$$

式中：A为景观总面积。

生态意义：%PLAND 等于某一拼块类型的总面积占整个景观面积的百分比。其值趋于 0 时，说明景观中此拼块类型变得十分稀少；其值等于 100 时，说明整个景观只由一类拼块组成。是确定景观中模地(matrix)或优势景观元素的依据之一；也是决定景观中的生物多样性、优势种和数量等生态系统指标的重要因素。

(3)斑块数(NP)，单位：无，范围：NP≥1

$$NP = N \tag{2.3}$$

公式描述：NP 在类型级别上等于景观中某一斑块类型的斑块总个数；在景观级别上等于景观中所有的斑块总数。

生态意义：NP 反映景观的空间格局，其值的大小与景观的破碎度也有很好的正相关性，一般规律是 NP 大，破碎度高；NP 小，破碎度低。

(4)斑块密度(PD)，单位：个/100hm^2，范围：NP >0

$$PD = \frac{1}{A}\sum_{j=1}^{n} N_i \tag{2.4}$$

$$PD_i = \frac{N_i}{A_i} \tag{2.5}$$

式中：PD 为景观总体斑块密度，PD_i 为第 i 类景观要素的斑块密度，A 为研究地区景观总面积。

生态意义：每平方千米(100hm^2)的斑块数，反映景观的破碎化程度与景观空间异质性程度。斑块密度越大，破碎化程度越大，空间异质性程度也愈大，反之亦然。当斑块密度指数按景观要素类型分别统计时，通过比较分析可以说明不同景观要素在景观空间结构中的作用和特点，可以研究不同类型景观的破碎化程度及整个景观(研究区)的景观破碎化状况，从而可以识别不同景观类型受干扰的程度。

(5)平均斑块面积(MPS)，单位：hm^2，范围：MPS >0

$$MPS = \frac{A}{N}10^6 \tag{2.6}$$

公式描述：MPS 在拼块级别上等于某一拼块类型的总面积除以该类型的拼块数目；在景观级别上等于景观总面积除以各个类型的拼块总数。

生态意义：MPS 代表一种平均状况，在景观结构分析中反映两方面的意义：景观中 MPS 值的分布区间对图像或地图的范围以及对景观中最小拼块粒径的选取有制约作用；另一方面 MPS 可以指征景观的破碎程度，研究发现 MPS 值的变化能反馈更丰富的景观生态信息，它是反

映景观异质性的关键。

(6)边缘密度(ED)，单位：m/hm^2，范围：ED≥0

$$ED = \frac{E}{A}10^6 \tag{2.7}$$

式中：E 为景观中某一类型边界总长度，或景观中所有斑块边界总长度(m)。

生态意义：某类景观要素斑块与其相邻异质斑块之间的边缘长度。说明斑块形状的不规则程度。ED 越大，说明边界越不规则。

(7)平均斑块形状指数(MSI)，范围：MSI≥1，无上限。

$$MSI = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\frac{0.25P_{ij}}{\sqrt{a_{ij}}}\right)}{N} \tag{2.8}$$

式中：P_{ij} 是斑块类型 i 与 j 相邻的概率，a_{ij} 为第 j 类景观要素第 i 个斑块的面积。

生态意义：指某类景观要素中每一斑块的周长(m)除以面积(m^2)的平方根，再乘以正方形校正常数，后对所有的斑块加和，再除以斑块总数。取值范围：MSI≥1，无上限。当景观中所有斑块为正方形时，MSI=1，当斑块的形状偏离正方形时，MSI 增大。

(8)Shannon 多样性指数(SDI)

$$SDI = -\sum_{i=1}^{n}(P_i \ln P_i) \tag{2.9}$$

式中：P_i 是第 i 类景观要素面积占景观总面积的比例，且

$$P_i = \sum_{j=1}^{N_i}\frac{A_{ij}}{A}$$

生态意义：反映景观要素的多少和各景观要素所占比例的变化。当景观是由单一要素构成时，景观是均质的，其多样性指数为 0；由两个以上的要素构成的景观，当各景观类型所占比例相等时，其景观的多样性最高；各景观类型所占比例差异增大，则景观的多样性下降。

(9)Shannon 均匀度指数(SEI)

$$SEI = \frac{H}{H_{max}} \tag{2.10}$$

式中：H 是 Shannon 多样性指数，H_{max} 是其最大值。显然，当 E 趋于 1 时，景观斑块分布的均匀度亦趋于最大。

生态意义：反映景观中各斑块在面积上分布的不均匀程度，通常以多样性指数和其最大值表示。

(10)优势度指数(D)

$$D = SDI_{max} + \sum_{j=1}^{n_i} P_i \ln P_i \tag{2.11}$$

式中: $SDI_{max} = \ln m$ ，它表示当研究区各类型景观所占比例相等时，景观拥有的最大的多样性指数。P_i 是第 i 类景观要素面积占景观总面积的比例，m 是景观中斑块类型总数。

生态意义：是景观多样性指数的最大值与实际计算值之差。它描述景观由少数几个主要景观类型控制的程度。优势度指数越大，则说明组成景观的景观类型所占比例差异大，或者说某一种或几种景观类型占优势，则该种景观要素对景观整体功能、结构控制作用较强；优势度小则相反。当优势度为 0 时，表示组成景观的各种景观类型比例相等。

2.3.3 景观动态预测模型

国内外有关景观动态模拟模型的研究很多，包括 Markov 模型(徐岚和赵羿，1993；韩文权和常禹，2004；卢景龙，2002)逻辑斯蒂回归模型(杨学军等，2001)及用分室理论模拟景观格局在不同干扰条件下的变化趋势(何东进等，2004)。Markov 链具有结构合理、实用性强及预测精度高等特征，在景观动态预测中始终受到重视(钟义山，1988；陈平留，1992；孙丹峰，2005；侯西勇等，2004)。

2.3.3.1 Markov 模型

Markov 模型是基于 Markov 过程理论形成的预测事件发生概率的一种方法，常用于具有无后效性特征地理事件的预测，现已成为景观动态建模的一条重要途径。一般认为以 Markov 模型为基础发展起来的景观模型隐含着 3 点基本假设：第一，景观的变化时一种随即过程而不是确定性过程，即景观要素的转化时一种概率事件，可用转移概率刻画。第二，景观空间格局由一个阶段向另一个阶段的转移或转化至依赖于目前的状况而与先前状况无关。第三，景观要素之间的转移概率不变。这正是此类模型建模较方便，参数较易确定，也是模型存在一定局限性的根源(郭晋平和周志翔，2007)。

景观动态模拟时，景观类型对应 Markov 过程中的“可能状态”，而各类型之间相互转换的面积数量或比例即为状态转移概率，可以利用式(2.12)和式(2.13)对景观变化进行预测：

$$S_{t+1} = P_{ij} \cdot S_t \tag{2.12}$$

式中: S_t 、S_{t+1} 分别为 t、$t+1$ 时刻的系统状态，P_{ij} 称为状态转移概率矩阵，可由式(2.13)表示：

$$P_{ij} = \begin{bmatrix} P_{11} \cdots P_{1n} \\ \vdots \\ P_{n1} \cdots P_{nn} \end{bmatrix} \tag{2.13}$$

式中：n 为景观类型，P_{ij} 表示由 i 类景观类型转变为 j 类景观类型的概率，同时 P_{ij} 必须满足以下两个条件：

(1)$0 \leqslant P_{ij} \leqslant 1$；

(2) $\sum_{j=1}^{n} P_{ij} = 1(i,j = 1,2,\cdots,n)$

2.3.3.2　*转移概率矩阵的确定*

Markov 模型有效性的关键是转移概率的确定是否合理(郭晋平和周志翔，2007)。本书在 GIS 支持下，通过各时期景观要素图层之间的叠加操作，确定不同时期各斑块保持不变的面积和转化为其他类型的斑块面积，计算各景观要素类型之间的转换面积占该类型原有面积的比率作为转移概率的估计值，从而确定转移概率矩阵。

2.3.4　外业调查

参照国家林业局 2003 年颁布的《森林资源规划设计调查主要技术规定》和海南省林业局 2008 年颁布的《海南省森林资源二类调查操作细则》，结合参与式调查方法，2008 年 11 ~12 月和 2009 年 3 ~5 月对陵水黎族自治县大敢 FLR 示范区进行小班区划与小班调查。

2.3.5　退化与次生森林特征分析方法

2.3.5.1　*群落学方法和测树学方法*

采用样地法进行群落学特征调查(王伯荪等，1996)。2009 年 3 月分别调查了示范区内 4 个退化原始林群落类型和 4 个次生林群落类型，每个群落类型设置一个面积为 720 m^2 的带状样地，每个样地由 20 个 6 m×6 m的小样方组成。对于退化原始林，测定每个样方内胸径 DBH≥5 cm 的所有林木；对于次生林，则测定每个样方内树高 $H \geqslant 1.3$m 的所有林木。每个样地内选择 2 个典型样圆，调查灌木层和草本层植物。采用 J . T. Curtis 和 R. P. McIntosh 提出的重要值概念进行重要值计算；结合群落学特征调查，进行测树学特征调查(孟宪宇，1996)。

2.3.5.2　*物种多样性测度*

采用物种丰富度、物种多样性指数、物种均匀度及生态优势度指标综合测度物种多样性，物种丰富度(R)采用物种的数目，即群落种的丰富度(S)；Shannon-Wiener 指数(SW)表示物种多样性；物种均匀度(E)采用 Shannon-Wiener 均匀度；生态优势度(ED)用 Simpson 生态优势度

（王伯荪等，1996）。各计算公式为：

$$SW = \sum_{i=1}^{S} P_i \cdot \log_2 P_i = 3.3219(\lg N - \sum_{i=1}^{S} n_i \cdot \lg n_i / N) \quad (2.14)$$

$$E = SW/\log_2 S \quad (2.15)$$

$$ED = \sum_{i=1}^{S} n_i(n_i - 1)/[N(N - 1)] \quad (2.16)$$

式中：SW 为 Shannon-Wiener 多样性指数，S 为种数，n_i 为第 i 个种的个体数，N 为群落(样地)全部个体总数，P_i 为第 i 个种的个体总数的百分数，E 为基于 Shannon-Wiener 多样指数的均匀度，ED 为 Simpson 生态优势度。

2.3.6 参与式农村评估(PRA)方法

参与式农村评估(participatory rural appraisal，缩写为 PRA)在国际上 80 年代广泛运用的农村快速评估(Rapid Rural Appraisal，缩写为 RRA)调查法的基础上结合其它调查研究法如农业生态系统分析、运用人类学、农耕系统研究等经过多年的发展演变(Chambers R，1994)，于 90 年代发展起来并迅速推广运用的农村社会调查研究方法，被称为“来自农户、与农户一道和依靠农户学习了解农村生活和条件的一种方法和途径”。虽然 PRA 是一个学习、了解的过程，它也扩展到分析、规划和采取相应行动的过程(李勉等，2000)。

PRA 的方法和途径发展很快，因此给出一个精确和最终的定义，未必会有帮助。可以这样理解 PRA：它是一种参与式的方法和途径，在外来者的协助下，鼓励当地人运用乡土知识，分析与他们生产、生活有关的环境和条件，制定今后的计划并采取相应的行动(Robert L，1993)，最终使当地人从中受益。PRA 已作为一个参与式工作方法的代名词，其含义是：参与式是指充分强调受益者作为项目活动主体的重要性，并重视受益者能力的提高；农村是指原来主要在农村实施，现在实际上已经扩展到了城市；评估是指贯穿自问题识别到项目实施与监测评价的整个过程(刘璨等，1999)。PRA 既是一种调查方法，又是一种促进当地居民参与项目周期管理的具体实践，通过使用 PRA 的各种工具，能让当地居民积极参与调查，了解他们所处的社区情况和面临的问题，使居民在项目实施中更主动，使项目的监测和评价更符合当地居民的标准，最终将项目转变为当地居民自己的项目(徐国祯，2002；左停，2004)。

本书用到的 PRA 工具包括直接观察、村民大会、森林调查、大事记、半结构访谈、特殊群体讨论会(穷人，妇女等)、参与式制图、问

题矩阵排序、村民需求评估等(李小云，2001；刘金龙等，2007)。

2.3.6.1　半结构访谈

半结构访谈(semi-structured interview)是相对于全结构访谈而言。后者的典型代表是问卷调查，即所有问题都是先考虑、设计好，甚至连集中答案都事先确定，因此是一种封闭式的调查方式。相反，半结构访谈则显得灵活和开放得多。访谈前它一般只拟定大纲性的议题，其中只有主题和次级主题是事先准备好的，因此在访谈中将依据主题逐渐展开对话。访谈的对象可以是个体、群体，对于个体一般是针对知情人，如村干部、老农等，而对于群体则多采用专题小组讨论。在半结构访谈中，常常要借助于所谓的“6 个助手”进行深入讨论，这“6 个助手”是用于提问的“谁、什么、为什么、什么时候、哪里、怎么样”，简称为“5W + 1H”。需要指出的是，访谈的当天要及时将访谈记录进行整理、归纳、总结。

2.3.6.2　资源图

资源图(resource mapping)是 PRA 图解法的一种，由于所含信息量大，因此往往成为 PRA 实地调研的开始，在涉及自然资源管理、土地利用调查、流域管理等研究课题时更是十分有用的工具。资源图是当地知情人(熟悉所在村、甚至流域情况)根据外啦协助者的提示在纸上绘制出的某一区域的大致的资源分布情况，如耕地、山地、道路、河流、水渠、学校等。在绘制过程中，诸如资源类型、优势、分布差异及发展制约因素等均能反映出来，而且是一种直观和空间的分布视图。参与式土地利用分类也在此基础上逐步展开。绘制资源图需要准备大纸、彩色记号笔等。

2.3.6.3　踏勘

踏勘(transect)是与当地知情人共同对某一区域选择一条穿越线并进行实地查看。在流域区，往往选择沿河流进行穿越踏勘。穿越中，通过知情人的沿途介绍，观察和分析地形地貌、土壤、植被、种植制度等、识别不同的土地利用现状类型、讨论土地资源利用存在的问题。在使用航片时，是共同判读航片的重要手段。对沿途观察、讨论的结果实地记录。在室内经过整理记录，可以绘制成生态剖面图，根据需要归纳总结出穿越线中典型地段的土壤、植被、土地利用方式及历史演变、存在问题等。

2.3.6.4　季节历

季节历(seasonal calendar)也是 PRA 的一种图解工具，用文字、符

号、线条、物品等来表示和分析农户经营系统的构成、季节变化及其相互间的关系。其用途是迅速了解农户的资源配置情况(土地、劳力、劳动时间等)，了解农户的劳动强度、男女分工的季节动态，分析投入、产出及其存在的问题。与季节历相似的是“一日活动时间图”，只是将时间单位换成了日。可以选择最忙和最闲季节中的一日，分析日工作或劳动类型。注意分析社会性别之间的差异，最好是男女分开来做。

2.3.6.5 矩阵排序

矩阵排序(matrix and ranking)是用重要性等级(打分)、数量序数(排序)并以矩阵表格的形式呈现，反映当地人的看法、观点，他们比较事务所使用的标准、依据和在不同事务之间做出的选择或比较，例如对资源分配、土地利用方式、贫富状况评价等(马焕成等，2001；田敏，2005)。使用工具的过程可以转移当地人的视线，不再注意外来者，而在他们之间展开讨论和分析，常能引发激烈的争论。矩阵排序常用于需求、问题和发展途径的分析。

2.3.6.6 问题树

问题树(problem tree)是利用连线、箭头来简要说明相关事物之间因果关系的一种图解方法，分析农户、村、流域的主要问题、原因和导致的(负面)影响。问题树是将讨论的原因、结果(因果链)以类似树的形式表现出来：树干为主要问题或核心问题，密布的树根是原因，而树的枝叶则是结果。使用问题树可以更加全面的诊断某区域或某事件中存在的主要问题及问题之间的相互联系，由此确定因果关系。

第三章　森林景观恢复内容与方法体系

森林景观恢复是一个旨在恢复伐后森林景观或退化森林景观的生态完整性和提高人类福利的过程。森林景观恢复提供了一种森林可持续经营的补充框架，是在毁林或森林退化导致生态系统服务质量下降的景观内实施的生态系统方法。森林景观恢复采用景观水平的观点，即立地水平的恢复决策需要满足景观水平的目标，需要考虑对景观水平的影响。这里强调的景观可以理解为目光所及、有冲突、有折衷、需要平衡土地利用的地理区域，这个区域所涵盖的空间实体可大可小。从理论角度讲，全球、国家、亚国家(洲或省)、市(地区)、县、乡镇、村等各级行政区域以及由大到小的各级流域(自然区域)都可以看成一个景观。但从实践角度讲，森林景观恢复主要涉及两个层面的景观，一个是操作层面的，另外一个是控制层面的。

操作层面的景观强调森林景观恢复措施的可操作性和“自下而上”的决策过程特点，自然村或行政村是最合适的尺度，而用“社区水平”又是最合适的表述。虽然社区也可以大到指地球社区，但通常理解的社区是“指固定的地理区域范围内的社会成员以居住环境为主体，行使社会功能、创造社会规范物，与自然村或行政村同一等级的行政区域”。控制层面的景观强调森林景观恢复的宏观调控作用和“自上而下”的决策过程特点，区域经济社会可持续发展中指的具体“区域”是最合适的尺度，用“区域水平”是最合适的表述。由于县是我国行政管理的完整基层单位，县域经济是我国国民经济的基础，县域是区域经济社会可持续发展的最基础的空间尺度。因此，在森林景观恢复中，分为“社区水平”和“区域水平”的森林景观恢复，其中“社区”指自然村或行政村，“区域”指县域或县域以上单元。本书案例研究中的“社区”指大敢自然村，“区域”指陵水黎族自治县。

本章以陵水黎族自治县森林景观恢复规划过程和大敢自然村森林景观恢复规划与实施过程为案例，从森林景观恢复内容与方法框架、利益相关者分析、建立 FLR 支持、景观镶嵌体分析、景观动态与驱动力分析、确定优先恢复立地、立地水平恢复策略、FLR 规划与实施和监测与评价等方面，研究适合中国国情与林情的区域水平和社区水平森林景观

恢复内容与方法体系的构建技术。

3.1 内容与方法框架

利益相关者分析、建立政府和公众对森林景观恢复的支持、分析景观镶嵌体及其动态、驱动力分析、确定立地水平恢复选择及优先恢复立地、立地水平恢复策略、FLR 规划与实施和监测与评价是实施森林景观恢复的主要内容和基本步骤，其中涉及利益相关者决策分析法、平衡土地利用折衷、联合决策制定、冲突管理机制等方法，“双重过滤器”、公众参与和适应性经营是整个过程必须遵循的原则。这些步骤、方法和原则共同构成了森林景观恢复的内容与方法体系，各内容与方法之间的相互关系如图 3-1。

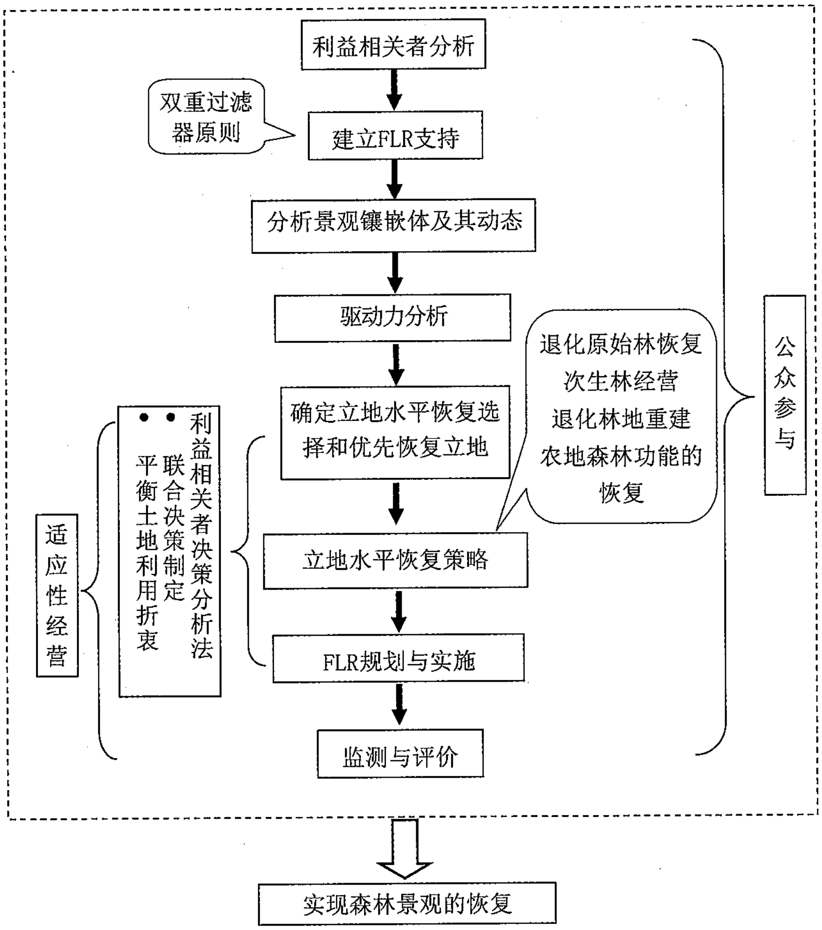

图 3-1 森林景观恢复内容与方法框架

3.2　利益相关者分析

实施森林景观恢复的第一步就是确定利益相关者及其利益。利益相关者，在这里定义为能直接或间接影响森林景观恢复倡议，或者直接或间接地受森林景观恢复倡议影响的个人、群体或组织。森林景观恢复倡议通常包括三类利益相关者：主要的利益相关者：森林景观恢复实施者，包括林业学术机构、林业工作人员、非政府组织、农民、社区、林业企业等；政府，包括国家和当地政府；次要的利益相关者：森林景观恢复相邻地区公众、当地木材相关企业、投资者等；第三类利益相关者：一般公众、旅游产业、林产品消费者等。

确定森林景观恢复中利益相关者的常用方法包括：①由利益相关者自己确定：森林景观恢复倡议的工作人员通过当地媒体或实地参观发布消息，邀请利益相关者参加会议；②由其他利益相关者确定：早期确定的利益相关者是其他利益相关者的信息来源；③由知识丰富的个人或小组确定：知识丰富的个人或群体可能包括村子的长者，林业机构工作人员或邻近的社区；④由森林景观恢复倡议的实地工作人员确定：实地工作人员在某一区域居住过一段时间，可能具有识别利益相关者的知识；⑤基于人口统计学的确定：基于人口统计特征，如年龄、职业和性别等确定社会小组。对于陵水黎族自治县来说，实施森林景观恢复倡议的利益相关团体包括：县林业局、县发展和改革局、县农业局、县国土环境资源局、县水务局、县扶贫办、县海洋与渔业局、县民宗局、县旅游局与土地利用相关的政府部门，以及省属国营南平农场、岭门农场和吊罗山林业局三个国有机构。

大敢 FLR 示范区的利益相关者包括当地村民、村民小组、森林社区、地方林业局、项目成员、各级政府、民间社会组织、教育与研究机构和资助者(见表 3-1)。其中示范区当地村民、村民小组和森林社区对森林的依赖性强，与森林景观恢复倡议关系最密切，并将从森林景观恢复倡议中获益。森林景观恢复将帮助他们实施森林恢复与重建活动，提高森林提供林产品和各种生态服务的功能，从而降低贫困、改善生计。地方林业局负责热带退化与次生森林的管理与保护工作，将直接参与森林景观恢复倡议的实地调查工作，并从中获得减少毁林和森林退化的管理经验。各级政府缺乏制定森林景观恢复规划和减少毁林与森林退化的相关信息，森林景观恢复倡议将提高各级政府恢复与重建退化与次生森林的机构能力，避免计划外的森林采伐和各种形式的森林退化，同时提

高热带森林对气候变化和人为影响的适应能力，为各级政府提供森林景观恢复的相关信息，并且由于森林景观恢复可以提高居民福利，从而减少对其他扶持机制和公益基金的需求。民间社会组织参与农村发展活动的实施，森林景观恢复倡议将提高其在社区发展和生态系统服务等方面的决策参与能力和活动支持能力。私有部门计划将退化与次生森林转化为速生丰产人工林，森林景观恢复将为其提供有关退化与次生森林新政策的信息，提高其森林可持续经营的实施能力。资助者和其他热带国家将得到改善现有资助策略和实地实施森林景观恢复的有价值的经验、教训和新知识。

表 3-1 大敢 FLR 示范区利益相关者分析表

利益相关者	特征	问题、需求、利益	潜力	参与程度
主要利益相关者				
当地村民 村民小组	森林所有者、从森林中获取收入、积极	贫穷、缺乏经济激励、缺乏替代收入来源	迫切需要获取帮助、具有传统知识、信任政府	直接参与 FLR 实施，FLR 主要受益人
森林社区	森林所有者、依赖退化与次生森林、积极	社区发展的基础受到威胁、缺乏经济激励	迫切获取帮助、具有传统知识、信任政府	直接参与 FLR 实施，项目主要受益人
地方林业局	负责森林可持续经营	减少毁林和森林退化的能力不足、缺乏实施 FLR 的经验	具有森林调查和村民工作的经验	直接参与 FLR 实施
当地政府	负责社区发展规划的制定与实施	缺乏 FLR 相关信息、缺乏恢复退化与次生森林的制度	管理和影响社区、具有制定实施 FLR 制度的权利	直接参与 FLR 实施
次要利益相关者				
民间社会组织	积极参与农村发展活动、并提供建议	缺乏为社区宏观发展提供建议的能力	具有农村工作的经验	帮助 FLR 倡议实施相关活动
私有部门	人工用材林所有者	缺乏森 FLR 的相关信息、需要寻求新的投资机会	具有采伐经验和投资能力	帮助 FLR 倡议实施相关活动
第三类利益相关者				
教育和研究机构	承担教育和研究任务	缺乏资助与合作途径	具有调查与研究能力	可能与 FLR 项目合作实施相关活动
资助者 金融机构	资助地方发展	缺乏资助与合作途径	具有资助地方发展的经验	可能参与 FLR 实施制度的制定

3.3　建立 FLR 支持

成功的森林景观恢复需要有地方和国家政策以及强有力的当地民众的支持。建立 FLR 支持，就是建立利益相关者对森林景观恢复倡议的支持。一般来说，通过资料收集、利益相关者分析、对利益相关者或利益相关团体代表进行森林景观恢复知识培训、参与式访谈和成立森林景观恢复工作小组来实现利益相关者对森林景观恢复的支持。

建立区域水平 FLR 的支持，可以通过举办培训班，提高不同利益相关团体对毁林和森林退化的理解，以及对森林景观恢复潜力的认识。培训内容涉及森林退化造成的经济和社会损失、森林景观恢复的概念、特征、方法和效益等一般性知识，以及全球范围内森林景观恢复成功案例的经验和教训。为了实现不同利益相关者之间纵向和横向的合作，有必要成立区域水平森林景观恢复正式或非正式机构。建立社区水平 FLR 的支持，可以通过村民大会、村民访谈等参与式过程，用通俗易懂的语言向利益相关者阐明森林景观恢复的相关知识。此外，充分利用广播、电视、宣传画等形式，不断与利益相关者协商、交流，以期提高公众意识，让政府、当地社区、居民明确森林景观恢复对降低贫困、促进经济增长、保障环境安全、保护生物多样性所起的作用(Elliott S，2000；Marghescu T，2001；Kerr J，2002)。

3.4　分析景观镶嵌体

各种景观要素斑块交错分布，有机地结合在一起就形成了景观镶嵌体。任何景观镶嵌体的组成和镶嵌体内部各要素的分布格局都是唯一的，景观要素不同，对森林景观恢复目标的作用也不同(Castillo-Campos 等，2008)。景观镶嵌体分析涉及数据获取、森林景观要素分类和景观格局分析等内容与方法(详见第四章)。

3.4.1　景观要素分类

从景观的土地分类、植被分类，到景观生态分类所建立的各种景观分类系统，都是在不同的研究目的、观察尺度和不同的分类原则和方法基础上形成和构建的，因此有必要针对具体研究区域或景观实际深入分析和研究。基于 FLR 的景观要素分类需要根据《ITTO 热带退化与次生森林恢复、经营和重建指南》和《ITTO 森林景观恢复手册》对退化原始林、次生林和退化林地等不同森林状态的界定，结合所收集的影像资料的分辨率和全国土地利用分类标准，从森林恢复与重建的角度，建立适

用于研究区森林景观格局分析的景观要素分类系统，其中必须划分出原始林、退化原始林、次生林、退化林地、农用地等景观要素类型。陵水黎族自治县景观要素分类体系包括：原始林、退化原始林、次生林、退化林地、橡胶林、村旁树、木麻黄人工林、其他人工林、其他林地、居住用地、园地、农用地和其他用地，共13类。

3.4.2 数据获取与处理

理解景观镶嵌体最常用的信息类型和信息来源见表3-2。如果有二类调查数据可直接应用，但常常没有符合要求的二类调查数据（如时间和经费等问题），此时利用遥感数据获取区域水平相关信息是满足区域水平森林景观恢复要求的不错选择。陵水黎族自治县只在1994年开展过一次二类调查，而且图面数据已丢失，因此本研究主要通过遥感手段获取景观格局分析的基础数据。社区水平数据获取应该在遥感图像信息提取的基础上，通过参与式区划与调查分解出不同权属、不同景观要素类型和不同经营历史的小班边界，每个小班的具体信息包括：地貌、坡位、坡度、利用现状、群落结构、植被盖度、林分长势、权属、经营历史、管理投入、转换或开发时限、潜在驱动因素、未来可能的利用方式等。在GIS工具支持下，形成示范区不同时期景观镶嵌图。分析景观格局时，应忽略权属的不同，以景观要素类型作为划分斑块边界的依据。制定立地水平恢复策略时，则以权属和景观要素类型为斑块划分的依据。

3.4.3 景观格局分析

景观水平的研究需要一些方法来定量描述空间格局，比较不同景观，分辨具有特殊意义的景观结构差异，以及确定景观格局和功能过程的相互关系等（郭泺等，2009）。景观格局数量研究方法，主要包括用于景观组分特征分析的景观空间格局指数、用于景观整体分析的景观格局分析模型以及用于模拟景观格局动态变化的景观模拟模型。区域水平和社区水平的森林景观格局分析都可以采用景观指数法描述景观镶嵌体，选择指数类斑面积（CA）、面积比（PLAND）、斑块数（NP）、斑块密度（PD）、平均斑块面积（MPS）、边缘密度（ED）和平均斑块形状指数（MSI）描述景观要素组成及斑块特征，选择面积、斑块总数、斑块密度（PD）、平均斑块面积（MPS）、边缘密度（ED）、平均斑块形状指数（MSI）、景观多样性指数（SDI）、均匀度指数（SEI）和优势度指数（D）描述景观格局总体特征。

表 3-2　制定 FLR 策略和活动时所需的景观镶嵌体主要成分的信息

景观镶嵌体主要成分		信息用途	信息来源
土地利用	土地利用方式（有林地、农地、草场等）	制定 FLR 规划	地图、遥感影像
	土地利用趋势（如森林面积的增减，森林退化的方向），不同利益相关者有不同的观点	制定总体恢复、重建策略	与政府官员、农民、科学工作者讨论，地方上的看法可能与官方观点有差异，必要时需再次确认
	人口分布、可用的劳动力	例如，识别进行恢复活动的时间	官方纪录、与参与者讨论，尤其是当地民众
	当地（乡土）的历史、生态知识	确认官方信息、传达恢复和重建的策略	与当地社区和在此工作的研究人员讨论
排水系统	景观物理特征（如等高线、河流等）	制定恢复、重建策略	地图、遥感影像
土地权属	土地权属	例如，明确主要利益相关者	合法地界，与土地所有者和经营者讨论
	所有权不同或有争议的历史遗产	明确恢复和重建策略的可持续性	官方纪录，与政府官员、NGO 和当地居民讨论
生物影响	杂草、害虫、濒危物种、生物多样性高的地区分布在哪里等问题	明确恢复策略	地图、遥感影像、出版物、地方知识、专家知识（政府和 NGO 科学家等）
其它	基础设施（包括道路、铁路、城镇和村庄）	总体规划	地图、遥感影像
	地质和土壤类型	确定适地适树等	地图、专业调查及乡土知识

此外，在分析景观格局的同时，还应该评价不同景观要素对森林景观恢复倡议的贡献。景观不同，所划分出的景观要素类型也不同，其中原始林、次生林、退化林地、人工林、农业用地等类型是森林景观恢复倡议实施立地水平恢复措施的主要类型，他们在森林景观恢复倡议中作用见表 3-3。例如，人工林可以发展为保护区周围的缓冲带，也可以作为连接需要恢复、重建的区域和防护林的廊道，从而发挥人工林的生态、社会功能。

表 3-3 不同景观要素对 FLR 倡议的作用

景观要素		对 FLR 倡议的作用
有林地	完整的天然林（大面积）	原始林具有高度保护价值和发展价值，是 FLR 倡议的关键部分，通常与景观中需要恢复或重建的区域相连
	完整的天然林（小面积）	具有重要的保护价值和发展价值，通过与需要恢复的森林斑块相连，提高其价值
	人工林	具有一定的保护和发展价值，通过合理经营提高其价值，也可以作为退化森林和保护区的缓冲带
	退化森林或灌木林（大面积）	是恢复和重建的主要目标
	退化森林或灌木林（小面积）	具有一定的保护和发展价值，通过恢复和重建，以及与景观其他部分相连接可以提高其价值
非林地	农业用地	合理经营，有助于实现 FLR 的目标
	农田树木	对保护和发展的目标有一定作用，尤其是与完整的森林斑块相联接的时候
	河岸带	是重要的栖息地和景观连接地，为保护当地和下游的水土，需要恢复或重建
	退化区域	需要恢复和重建，用于天然林斑块的连接，有助于当地社区发展和环境保护
	侵蚀区，塌方区	需要特殊保护

3.5 景观动态与驱动力分析

森林景观恢复是对森林景观整体结构与功能的恢复，而我们所经营和恢复的森林景观又是动态因素的产物，景观的动态特征表现在其空间结构在不同时空尺度上的变化。在森林景观恢复实施前，不仅要理解森林景观动态，还必须分析出森林景观变化的动因。

3.5.1 景观动态分析与预测

通过对景观指数和研究区遥感影像进行综合分析，详细揭示研究区的整体景观结构及其动态。区域水平景观动态分析选择指数类斑面积（CA）、面积比（PLAND）和斑块数（NP）来说明各景观要素组成结构的变化，选择斑块密度（PD）和边缘密度（ED）说明景观要素类型的异质性变化，选择面积、斑块总数、斑块密度（PD）、边缘密度（ED）、景观多样性指数（SDI）、均匀度指数（SEI）和优势度指数（D）说明景观格局总体特征的变化。社区水平景观动态分析可以从景观各组分的变化（即林地、

农用地或居民点等各种景观要素的组成）和单个景观要素状态的变化（如林地向农用地的转化）这两方面分析。区域水平和社区水平的景观动态预测都可以采用 Markov 模型。通过两个途径构建转移概率矩阵：一是在 GIS 支持下，通过各时期景观要素图层之间的叠加操作，确定不同时期各斑块保持不变的面积和转化为其他类型的斑块面积，计算各景观要素类型之间的转换面积占该类型原有面积的比率作为转移概率的估计值，从而确定转移概率矩阵；二是采用系统抽样调查法，在地形图上进行等距抽样，利用实地调查或参考二类调查数据获得不同各样点的属性（景观要素类型），通过对不同时期相同样点上景观要素类型之间的变化数据进行整理和统计分析，确定各时期不同景观要素类型之间的样点转移频数，由转移频数计算转移概率，作为景观要素转移概率的估计值。

3.5.2　驱动力分析

采用转移概率矩阵和参与式调查相结合的方法，分析区域水平和社区水平森林景观动态变化的驱动力。通过分析转移概率矩阵，可是得出每一景观要素类型的增减来源，如退化原始林面积的减少是因为这一类型不断向次生林演化，而由退化原始林转移而来的次生林面积远低于次生林向橡胶林、农用地、退化林地等其他类型的转移，是造成次生林面积持续减少的原因，但是驱动这种转移的因素却不能由转移概率矩阵的分析得出。因此，在转移概率矩阵分析的基础上，通过参与式方法，如半结构访谈、矩阵排序、问题因果分析、头脑风暴等，与利益相关者或利益相关团体代表不断交流、讨论，结合不同地区的居民访谈、实地考察和查阅相关文献资料，充分利用现有的资源环境数据和社会经济数据，尤其是对森林利用和生态环境保护有重要影响的各类政策、法规数据，来分析社会、政策和人文因子对森林景观变化的影响，得出区域水平或社区水平景观格局变化的驱动因素。

3.6　确定优先恢复立地

森林景观恢复的重要特征之一是在景观框架下做出立地水平的恢复选择，在选择需要进行干预的立地时，必须从景观和立地两个水平上全面考虑。在景观水平上，首先要确定残余的、未经破坏的森林，特别是那些高保护价值森林，然后以此为起点，逐步开展具体的立地水平的干预（Hobbs 和 Norton，1996）。由于各种生态因素、社会经济因素的限制和利益相关者观点的差异，不可能恢复景观内所有森林，但是通过系统

地综合各种恢复措施，景观的主要生态功能将得到改善，生物多样性得到恢复，从而提高景观内居民福利。

3.6.1 影响立地水平恢复选择的因素

影响立地水平恢复选择的生态因素：①现有林木覆盖率：将决定森林采伐后的天然更新情况；②土壤肥力：决定是否借助先锋树种甚至是外来引种进行补植或造林；③物种丰富度：决定提高森林生物多样性的具体措施；④退化和破碎化程度：退化和破碎化程度越高，所需恢复成本越高。

影响立地水平选择的社会经济因素：①政策支持：相关政策的支持利于恢复措施的实施，如《海南省沿海防护林建设与保护规定》对恢复沿海防护林的支持；②对传统林产品的依赖程度：具有特殊价值的天然林产品（如药材）的供应下降，且无替代来源时，恢复活动容易实施；③是否有林产品/服务市场：若有林产品/服务市场，恢复活动相对容易实施，尤其是天然林产品的供应受到限制时；④经济收益的时间：恢复活动的经济回报时间越短越容易实施；⑤风险：成本低的恢复措施（如次生林保护）风险也低，种植速生树种更具有吸引力；⑥财政激励措施：恢复初期的财政补贴必不可少，生态补偿非常具有吸引力；⑦利益相关者的知识水平：决定利益相关者对恢复活动的参与支持程度。

3.6.2 优先恢复立地类型

确定景观优先恢复立地有许多适用原则：①25°以上开垦为农地的陡坡地，应当逐步退耕、植树和种草：根据《中华人民共和国水土保持法》第十四条和《中华人民共和国森林法实施条例》第二十二条的规定；②严格保护现有未经干扰的或经营良好的天然林（主要是原始林）：在现有天然林周围进行人工造林是防止进一步退化的良好途径；③禁止退化原始林和次生林转为人工林、经济林或农业用地：采取保护、天然更新或补植珍贵乡土树种的方式予以恢复；④在残存天然林间建立森林廊道：若森林连接或廊道结构复杂、物种丰富，则提高生物多样性的效果最好，人工纯林也可以作为现有天然林之间的廊道；⑤在道路两侧、河流两岸建立森林廊道，形成缓冲区；⑥恢复并保护沿海防护林带：根据《海南省沿海防护林建设与保护规定》第三条的规定；⑦对水源涵养林、水土保持林、防风固沙林等防护林只准进行抚育和更新性质的采伐：根据《中华人民共和国水土保持法》第十六条的规定；⑧特殊物种栖息地、崩塌滑坡危险区和泥石流易发区等具有重要生态功能的立地，应予以保护或恢复。

基于以上原则，在与利益相关者协商、交流后，确定区域水平和社区水平的优先恢复立地(详见附录1和附录2)。其中陵水黎族自治县优先恢复立地类型包括：退化原始林和次生林、退化林地、坡度大于25°的农地、连接次生林孤岛(斑块)的森林廊道、道路两侧护路林和河流两岸缓冲带(绿色廊道)、水库周边水源涵养林、农田防护林网。大敢FLR示范区优先恢复立地类型包括：退化原始林、次生林、退化林地、坡度大于25°的农地、连接山脊退化原始林或次生林的人工林(山脊生态廊道)、道路两侧护路林和河流两岸缓冲带(绿色廊道)。森林景观恢复规划的制定主要是对优先恢复立地的恢复措施进行时空安排，依靠利益相关者完成规划的实施。

3.7　立地水平恢复策略

森林景观恢复的目的不是还原森林景观到最初的"原始(pristine)"状态，而应该作为一种前瞻性的方法，加强景观恢复能力，利于将来的恢复选择。森林景观恢复的单独应用将是一套基于立地的灵活技术：从单纯的块状植被生态恢复到农田树种的种植，其综合作用将带来显著的景观效益。立地水平的技术包括：退化原始林的改造和主动经营、次生林生长量的主动经营、退化林地主要森林功能的重建、退化林地和边缘农业用地上天然更新的促进、生态恢复、造林和人工林、林农间作和其他农林结构(configurations of on-farm trees)。任何森林景观恢复倡议可以包括以上一条或多条。事实上，森林景观恢复的基本特点是各种解决问题的技术方法的融合运用，而不是依靠某一特定类型的干预。

3.7.1　退化与次生森林林分特征分析

从森林经营角度探讨退化与次生森林的林分特征，有助于因地制宜地确定立地水平的恢复措施。通过群落主要优势种的表现、群落结构、乔木层物种多样性(物种丰富度、物种多样性指数、物种均匀度及生态优势度等指标)、灌木层与草本层中的乔木幼树与幼苗组成与密度，林分生长(林分平均胸径、平均树高、平均密度和单位面积蓄积量等)、林分结构(树种、直径、树高和材积等结构)等方面揭示退化与次生森林的群落学与测树学特征(详见第七章)。

3.7.2　主要恢复策略

(1)退化原始林的保护与天然恢复：退化原始林仍然保留了早先原始林的主要特征，如树种组成、土壤结构、林分结构等，具备天然更新的能力，仍然具有重要的生态保护功能，因此恢复的基本原则是"减

压”，即只要对需要恢复的立地进行封禁保护，避免进一步的干扰，如毁林、木材和非木材林产品的过度收获和刀耕火种等，就可以依靠群落的天然更新和自然演替过程实现生态系统生物多样性、结构、功能和生产力的恢复，促进退化原始林向经营原始林、甚至是原始林的转变。该模式也称为“被动恢复”模式。促进退化原始林有效保护的另一措施是种植绿色隔离带。在退化原始林分与人工林、退化林地或农地的边界上种植马占相思(*Acacia mangium*)、桉树等速生树种作为绿色隔离带，可以有效界定退化原始林，避免进一步的人为干扰。

(2)次生林的保护与补植：由退化原始林皆伐后自然演替形成的次生林，乔木层仍有珍贵乡土树种，灌木层和草本层有丰富的乔木幼树幼苗，因此采取与退化原始林相同的恢复措施——保护性“减压”，建立绿色隔离带，尽量阻断人为干扰，利用现有幼树、幼苗，实现天然恢复。开发用作其他用途、后荒弃10年以上形成的次生林，乔木层仍有重要的商品材树种，但是缺乏珍贵乡土树种，因此这类次生林的恢复采取保护与补植相结合的措施，利用现有幼树、幼苗进行保护性恢复，再加上人工介入种植一些珍贵乡土树种，如降香黄檀、土沉香等，尽可能利用乡土树种定向恢复以高经济价值林木为目标的森林群落，以提高生态完整性和社区居民福利。恢复开发后弃荒形成的次生林所面临的最大冲突是保留次生林还是开发为人工经济林，并且决定权在于村民，也就是说这类次生林随时都面临再次开发的干扰，具体恢复活动的实施如树种选择必须与林地所有者进行反复协商，选择村民能接受的珍贵乡土树种，以便在经济收益与生态服务间找到均衡点，即满足森林景观恢复的“双重过滤器”原则。

(3)退化林地的重建：退化林地应以重建为主，即人工造林，在人工造林过程中尽可能保留残留的天然幼树。针对土壤条件差、碎石较多、经常遭受人为扰动、坡度陡的严重退化林地，首先种植生长快、抗旱、耐热、抗病虫害的先锋树种作为保育木，必要时采用外来树种，改良土壤，然后在下层种植珍贵乡土树种，下层林木生长起来后砍伐保育木，增加苗木所需光照。通过这种方式，既能加速退化林地生态系统的重建，又能提高当地村民的收入。由于这类林地为开发后弃荒形成，其使用权归当时的开发户主所有，因此在树种选择和具体恢复活动的实施上，应充分考虑村民的价值取向，依靠村民完成恢复活动。

(4)农地森林功能的恢复(混农林业)：对于分布相对集中的农地，可以发展农田防护林网，充分发挥农田树木在改善农田小气候、防风固

沙、抵御自然灾害、提高生态系统连通性等方面的积极作用，同时收获的林产品还可以为当地社区带来一定的经济收入。对于分布零散、占据特殊生态位置的农地，如位于河流、道路两旁、水库周边和坡度大于25°的陡坡的农地，应列为森林景观恢复的优先恢复立地，通过发展混农林业逐步将其转成林地。混农林业追求农林牧平衡发展，树种应选择珍贵、经济价值高的乡土树种，并在种植初期发展农作物和林下经济作物的套种，以增加林产品收获的经济收益。为了利于农作物和机械化施工，林木密度必须控制，同时在配置上，要考虑农林作物在一定气候条件下不同季节的水肥关系，防止不利竞争，而且在林木不同生长阶段，相应调整农作物种类，以及考虑放养相应的畜禽。

3.8　监测与评价

森林景观恢复倡议的各种活动面临巨大的社会、经济、文化和技术挑战，监测与评价可以为这些变化提供信息。监测是用一套可变的指标，以测量受到干扰的景观内的社会经济和环境条件变化。监测应重点放在未取得既定目标的干扰的方面，监测结果要广泛散布，以利于将来的决策制定。评价是对正在进行的或完成的活动，系统的、客观的评估，考虑了活动的设计、实施和影响，以确定目标是否已经完成，重点是理解成功和失败的原因，为未来的工作或其他类似的干扰提供经验。与监测不同，评价不是连续过程，而是在干扰中间和最后进行。监测与评价是建立在详细理解森林景观恢复干扰内容的基础上，因此，恢复活动初期的计划阶段就要准备监测与评价计划，并且监测与评价技术要贯穿森林景观恢复的始终。

监测与评价作为森林景观恢复适应性经营的基础和依据，其核心是建立一套指标体系对森林景观恢复的环境和实施进行合理评价，揭示当前恢复活动存在的问题和确定将来恢复选择的方向。指标体系的构建应遵循三个原则：①科学性原则，这是确保监测与评价结果准确合理的基础，森林景观恢复的规划和实施是否科学很大程度上依赖其具体工作方法是否科学。指标体系的科学性是指指标体系应围绕监测与评价目的，全面反映森林景观恢复的内容，不能遗漏重要方面或有所偏颇，应反映评价内容的特征，含义清晰，各指标之间应协调统一，层次结构合理。②目的性原则，指标体系应是对监测与评价对象的本质特征、结构及其构成要素的客观描述，应为不同干预措施的目的服务，能够支撑适应性原则。③实用性原则，建立指标体系应考虑到现实的可能性，指标体系

应符合国家政策，适应于指标使用者对指标的理解接受能力和判断能力，适应于信息基础，森林景观恢复的实践性很强，指标体系的实用性是确保监测与评价实施效果的重要基础。基于以上原则，本研究从过程和结果两方面构建了森林景观恢复监测与评价指标体系（见表3-4），共77个指标。需要说明的是，指标体系不是固定不变，应根据森林景观恢复实施地点的具体情况而定，并且可以随时调整和补充。

表3-4　FLR监测与评价指标体系

	因素	指标
过程指标	1 利益相关者参与	1.1 利益相关者和特殊目标群体的界定
		1.2 利益相关者的能力和地位
		1.3 利益相关者在FLR过程中的职责
		1.4 弱势群体，如贫民，注意性别平等
		1.5 制定FLR方案初期利益相关者的参与程度
		1.6 FLR实施与监测的参与度
		1.7 社区发展的领导人/组织
	2 利益相关者协商	2.1 信息共享的质量和范围
		2.2 利益相关者间的伙伴关系
		2.3 利益相关者的协调
		2.4 讨论并解决问题的协商机制的制度化
	3 服务的提供	3.1 利益相关者的满意度
		3.2 利益相关者获得的服务
		3.3 利益相关者获得咨询和支撑的程度
		3.4 工作计划和时间表的遵守
		3.5 FLR目标的实现程度
	4 社区需求评估及评估结果传播	4.1 信息与交通工具
		4.2 弱势群体的需求
		4.3 社区的满意度
		4.4 社区对FLR干预活动的参与程度
		4.5 评估结果的传播途径与范围
	5 利益相关者能力建设	5.1 采取的示范行动
		5.2 项目活动的实施
		5.3 冲突分析与解决机制
		5.4 地方自治机构的能力提高
		5.5 妇女的组织能力
	6 实施	6.1 关键利益相关者的合作
		6.2 恢复活动的激励机制
		6.3 吸取经验教训的灵活性

（续）

	因素	指标
结果指标	7 FLR 实施机构能力的加强	7.1 实施机构的财政情况 7.2 多学科工作人员的能力建设 7.3 认证产品的数量 7.4 维持项目成果的机构能力
	8 综合资源管理	8.1 经过批准的经营方案（用材林、流域管理、保护区等） 8.2 产品多样性（木材和非木材林产品、环境服务） 8.3 现有的土地利用规划
	9 景观格局与林产品	9.1 各景观要素类型的面积及面积比 9.2 各景观要素类型的破碎度 9.3 景观多样性 9.4 退化与次生森林的现状 9.5 林产品类型与收获量 9.6 非木质林产品的可持续收获情况 9.7 资源利用程度 9.8 资源利用者的多样性 9.9 现有的退化森林恢复方案
	10 生态完整性恢复	10.1 恢复后的森林覆盖率 10.2 物种多样性 10.3 森林结构 10.4 天然更新的森林面积 10.5 造林面积 10.6 野生动植物的保护措施 10.7 野生动物栖息地的恢复情况 10.8 恢复的森林功能 10.9 连接森林生态系统的廊道现状 10.10FLR 中乡土知识的应用情况 10.11 流域的集水量 10.12 恢复前后土壤侵蚀程度 10.13 林火频率 10.14 森林碳汇 10.15 恢复对人类活动的影响（家养动物、作物生产等）
	11 社区收入来源	11.1 可用的森林资源 11.2 森林资源的获取与利用方式 11.3 木材/薪炭材的供应量 11.4 人工林的饲料供应量 11.5FLR 产生的就业机会 11.6FLR 针对特殊目标群体的就业机会（妇女、部少数民族、青年等） 11.7 社区居民收入变化

（续）

	因素	指标
结果指标	12 财政收益	12.1FLR 的成本与效益 12.2FLR 对当地财政的贡献 12.3 当地林业产业的收益
	13 参与式监测与评价	13.1 监测工具 13.2 生态信息和社会经济信息的来源 13.3 数据收集的方法 13.4 监测与评价的执行机构 13.5 监测与评价的公众参与程度 13.6 监测与评价对报告的贡献 13.7 经验教训

3.9 小　结

在全面总结国内外森林景观恢复理论和实践的基础上，结合中国的国情和林情，初步提出区域水平和社区水平森林景观恢复的内容与方法框架，通过在陵水黎族自治县和大敢村(FLR 示范区)的实地应用与研究，构建了区域水平和社区水平森林景观恢复的内容与方法体系。

(1)利益相关者分析、建立政府和公众对森林景观恢复的支持、分析景观镶嵌体及其动态、驱动力分析、确定立地水平恢复选择及优先恢复立地、立地水平恢复策略、FLR 规划与实施和监测与评价是实施森林景观恢复倡议的基本步骤，其中涉及利益相关者决策分析法、平衡土地利用折衷、联合决策制定、冲突管理机制等方法“双重过滤器”、公众参与和适应性经营是整个过程必须遵循的原则，这些步骤、方法和原则共同构成了森林景观恢复的内容与方法体系。

(2)采用确定利益相关者的常用方法，明确陵水黎族自治县实施森林景观恢复倡议的利益相关团体和大敢 FLR 示范区的利益相关者，并从特征、问题、需求、利益、潜力和参与程度等方面进行利益相关者分析。陵水黎族自治县的利益相关团体包括：县林业局、县发展和改革局、县农业局、县国土环境资源局、县水务局、县扶贫办、县海洋与渔业局、县民宗局、县旅游局与土地利用相关的政府部门，以及省属国营南平农场、岭门农场和吊罗山林业局三个国有机构。大敢 FLR 示范区的利益相关者主要包括当地村民、村民小组、森林社区、地方林业局、项目成员、各级政府、民间社会组织、教育与研究机构和资助者。

(3)成功的森林景观恢复需要有地方和国家政策以及强有力的当地民众的支持。通过资料收集、利益相关者分析、对利益相关者或利益相

关团体代表进行森林景观恢复知识培训、参与式访谈和成立森林景观恢复工作小组来实现利益相关者对森林景观恢复的支持。为了实现不同利益相关者之间纵向和横向的合作，有必要成立区域水平森林景观恢复正式或非正式机构。

(4)区域水平和社区水平的景观镶嵌体及其动态分析都可以通过景观要素分类、数据获取与处理、景观格局分析、景观动态分析与预测、驱动力分析等步骤来实现。二类调查、遥感信息提取和抽样调查是获取区域水平景观格局分析基础数据的三种方法。社区水平数据获取应该在遥感图像信息提取的基础上，通过参与式小班区划与调查分解出不同权属、不同景观要素类型和不同经营历史的斑块边界。

(5)根据影响立地水平恢复选择的生态因素、社会经济因素和利益相关者观点的差异，提出确定优先恢复立地的适用原则，并根据这些原则分别确定陵水黎族自治县和大敢 FLR 示范区的优先恢复立地。其中陵水黎族自治县优先恢复立地类型包括：退化原始林和次生林、退化林地、坡度大于25°的农地、连接次生林孤岛(斑块)的森林廊道、道路两侧护路林和河流两岸护岸林(绿色廊道)、水库周边水源涵养林、农田防护林网。大敢 FLR 示范区优先恢复立地类型包括：退化原始林、次生林、退化林地、坡度大于25°的农地、连接山脊退化原始林或次生林的人工林(山脊生态廊道)、道路两侧护路林和河流两岸护岸林(绿色廊道)。

(6)通过群落主要优势种的表现、群落结构、乔木层物种多样性、灌木层与草本层中的乔木幼树与幼苗组成与密度，林分生长、林分结构等方面揭示退化与次生森林的群落学与测树学特征，结合参与式调查，提出立地水平恢复策略：退化原始林的保护与天然恢复、次生林的保护与补植、退化林地重建(人工造林)、混农林业。

(7)遵循科学性、目的性和实用性原则，从过程和结果两方面构建了森林景观恢复监测与评价的指标体系，共77个指标，作为森林景观恢复适应性经营的基础和依据。

第四章　区域水平景观格局分析

本章以陵水黎族自治县为例，从景观要素分类、数据获取与处理、景观格局与动态分析等方面，研究区域水平景观格局分析技术。

4.1　基于 FLR 的景观要素分类

景观是由相互作用的、以某种方式重复出现的异质生态系统组成的陆地区域，这些异质生态系统，可称之为景观要素。森林景观分类即是确定景观构成要素及其空间分布格局，是在大尺度上探讨森林生态系统整合问题的基础。森林景观要素的划分是开展森林景观生态研究，揭示森林景观格局、生态功能和动态变化过程的基础，也是为森林景观建设、管理、保护和恢复进行规划设计的基础。目前我国森林景观格局研究中的景观要素分类，大多从森林生态或森林经营的角度，以土地利用类型及植被优势为主要依据建立景观要素分类系统，在土地利用现状图、林相图、地形图等图件资料或在航片判读、卫星影像解译的基础上，绘制森林景观类型分布图(菅利荣，2001；亢新刚，2001；张涛等，2002；孙玉军，2003；何东进，2004)，也有少数研究基于森林资源二类调查数据进行景观要素分类(陆元昌，2005)，但未见从森林退化状态和森林恢复与重建的角度划分景观要素的研究。

森林景观恢复具体到立地水平主要是退化原始林恢复、次生林经营、退化林地重建和农业用地森林功能的恢复技术，因此实施恢复活动以前，必须分析研究区的退化原始林、次生林、退化林地和农业用地的分布与特征。本章根据《ITTO 热带退化与次生森林恢复、经营和重建指南》和《ITTO 森林景观恢复手册》对退化原始林、次生林和退化林地等不同森林状态的界定，结合所收集影像资料的分辨率和全国土地利用分类标准，从森林恢复与重建的角度，建立了适用于研究区森林景观格局分析的森林景观要素分类系统：原始林、退化原始林、次生林、退化林地、橡胶林、村旁树、木麻黄人工林、其他人工林、其他林地、居住用地、园地、农用地和其他用地，各类型的描述与说明见表 4-1。

表 4-1　陵水黎族自治县景观要素分类系统

代号	景观要素类型	描述与说明
1	原始林	未受到人类干扰的森林，或受到狩猎、伐木的影响非常小，天然结构、功能和动态过程未发生超过生态系统恢复能力的森林
2	退化原始林	在起初有原始林或天然林分覆盖的地区，由于木质和/或非木质林产品的不可持续收获，导致森林结构、过程、功能和动态的变化超出了生态系统的短期恢复能力的原始林
3	次生林	原有森林植被大面积采伐后(即低于原有森林覆盖的 10%)，林地上重新生长的木本植被，通常在废弃轮垦地、固定农业用地、牧场或造林失败地上自然发育而成
4	退化林地	原有林地由于木质和/或非木质林产品的过度收获、不合理的经营、反复火灾、放牧或其他损害土壤和植被的干扰或土地利用，而受到了严重破坏，其破坏程度已阻碍或严重推迟了放弃利用后的森林重建工作
5	橡胶林	种植橡胶的林地
6	村旁树	房前屋后的树木
7	木麻黄人工林	木麻黄是主要的沿海防风树种
8	其他人工林	桉树等人工林
9	其他林地	除以上类型以外的林地
10	居住用地	指供人们日常生活居住的房基地(有独立院落的包括院落)
11	园地	主要指荔枝、杧果、槟榔等经济林
12	农用地	种植农作物的土地，包括水田、旱地等
13	其他用地	河流、水库、湖泊、沙地等未列入以上其他类型的土地

4.2　数据获取与处理

二类调查数据是区域水平景观格局分析首先要考虑利用的基础数据。陵水黎族自治县只在 1994 年开展过一次二类调查，而且图面数据已丢失，因此利用遥感数据进行信息提取是满足景观格局分析要求的有效方法。

4.2.1　现有资料的收集

收集了研究区的多期遥感影像(详见附录 3)，其中完全覆盖陵水黎族自治县县域的三期数据为：1991 年 10 月 30 日获取的 LANDSAT-TM 影像，共 7 波段、分辨率 30m；1999 年 12 月 31 日获取的 LANDSAT-ETM 影像，7 波段、分辨率 30m；2008 年 5 月 15 日获取的 SPOT2 的多光谱和全色影像，多光谱三波段、分辨率 20m，全色波段分辨率 10m。高分辨率数据为：1999 年的航片数据，分辨率 1m，覆盖了绝大部分区

域，山区部分为彩红外影像；2006 年的 SPOT5 融合影像，分辨率 5m，覆盖了绝大部分区域；2007 年时收集陵水黎族自治县 1997 年土地利用现状图、1996 ~2010 年土地利用规划修编图、2006 ~2020 年土地利用总体规划图等图件。

4.2.2 图像校正及处理

从 1：10000 地形图上选取明显地物点，作为控制点对所有影像进行了校正。由于北部山区明显地物点少，影像校正误差较大。对校正后的 2008 年的 SPOT2 影像的多光谱和全色波段进行融合，融合后的影像分辨率为 10m。对 1991 和 1999 年的 TM 影像选取三波(4、5、1)段形成假彩色影像，用于目视解译。

4.2.3 图像信息提取及解译

信息提取采用自动分类和目视解译相结合的办法进行。首先对 TM 和 SPOT 影像进行大类的自动分类，分为水域、植被、裸地。再根据各时期的 TM 影像、SPOT 影像参考高分辨率影像建立对应的解译标志；通过对比同时期一类抽样调查数据验证及修改解译标志，进一步通过目视解译细分大类到小类。其中，目视解译 1991 年 TM 图像，参考 1993 年一类调查数据(89 个样地)；目视解译 1999 年 TM 图像，参考 1998 年一类调查数据(89 个样地)、1999 年黑白航片(山区部分彩红外航片)和 2000 年遥感调查成果；目视解译 2008 年 SPOT2 影像，参考 2007 年的 ALOS、2006 年的 SPOT5 数据，一类样地(89 个)和二类样地(544 个)的抽样调查数据。目视解译主要依靠高分辨率影像确定类别，高分辨率影像处理为近天然彩色，解译标志详见表 4-2。通过目视解译，划分出最后的图斑，分别形成 1991、1999 和 2008 年陵水黎族自治县景观镶嵌图(详见附录 5)。

表 4-2 陵水黎族自治县不同景观要素类型遥感解译标准

类型	影像特征及分布	类型	影像特征及分布
原始林	片状集中分布，位于吊罗山保护区的核心区，深绿色、有绒感纹理均一	退化原始林	片状，只在吊罗山保护区有分布，绿色较原始林淡，有绒感纹理均一
次生林	片状、分布在丘陵和山区，绿色夹杂棕色	退化林地	小片状、形状不规则，分布于山区、丘陵的林地中，棕色或粉棕色
橡胶林	由道路及空地分割、形状较规则的块状，分布在平原及低矮丘陵地带，纯绿色、纹理粗糙、有立体感	村旁树	围绕村庄和房屋分布，以印度紫檀、椰子、槟榔为主，呈颗粒状，绿色

（续）

类型	影像特征及分布	类型	影像特征及分布
木麻黄人工林	成片状、深绿色、纹理有毛发感，紧靠沿海潮间带分布	其他人工林	桉树成片状、绿色、纹理均匀，在平原、山坡分布
其他林地	未成林造林地，规则片状分布，有隐约的绿色，以裸土地的颜色为主，采伐迹地呈裸土地色彩，根据外业调查数据判定	居住用地	若干小矩形（屋顶形状）紧密相连在一起，成片状，居民地色调呈深灰，成片的居民地内有道路或街道
园地	由道路分割成片状图形、排列整齐，嫩绿色夹杂棕色，色调较均一	农用地	呈片状，有规则的格网状，地面平整，有田埂，生长作物的为嫩绿色，收割后因含水量不同呈深棕或浅棕色
其他用地	水的色调是灰黑、或蓝色；水库呈面状、有白色拦水坝；河流弯曲带状；湖泊和坑塘的水面色调呈均匀的浅黑色、蓝色或灰色；沙地呈白色或灰白色，色调统一，缺少纹理	—	—

4.3 森林景观格局现状

4.3.1 景观要素组成及斑块特征

景观要素组成结构是不同景观类型的种类、数量和相对数量关系，可以用景观要素类型的斑块数量、面积及其在景观中的分布情况来反映，景观要素斑块特征则主要通过斑块大小或规模、斑块形状等指数来反映。分别统计陵水黎族自治县 13 个景观要素类型的类斑面积（CA）、面积比（PLAND）、斑块数（NP）、斑块密度（PD）、平均斑块面积（MPS）、边缘密度（ED）和平均斑块形状指数（MSI），结果见表 4-3。

陵水黎族自治县总面积 108611hm^2，其中农用地面积最大，为 26651hm^2，有 829 个斑块，占景观总面积的 24.54%，以灌溉水田和旱地为主，主要分布在丘陵低洼地和平原地区，地形因素造成农用地面积小、斑块数多的现状（详见附录 5）。其次是次生林（24764hm^2），占总面积的 22.80%，斑块数为 344，主要位于北部浅山地区和整个丘陵地区。园地面积为 8693hm^2，占总面积的 8.00%，分布范围广，从北部浅山地区、整个丘陵地区、中部平原地区到沿海地区均有分布。橡胶林和村旁树的面积在整体景观中也占有较大比例，分别为 7.66%、6.78%，居第六、第七位，橡胶林主要分布在西部丘陵和陵水河上游平原地区，

表 4-3 陵水黎族自治县 2008 年森林景观要素特征

景观要素类型	类斑面积 CA(hm^2)	面积比 PLAND%	斑块数 NP(n)	斑块密度 PD (个/100hm^2)	平均斑块面积 MPS (hm^2)	边缘密度 ED (m/hm^2)	平均斑块形状指数 MSI
原始林	5153	4.74	11	0.21	468.43	38.39	2.31
退化原始林	6837	6.29	110	1.61	62.15	57.52	2.00
次生林	24764	22.80	344	1.39	71.99	68.23	35.14
退化林地	2358	2.17	766	32.48	3.08	341.38	1.82
橡胶林	8324	7.66	58	0.70	143.51	104.87	19.42
村旁树	7365	6.78	505	6.86	14.58	265.76	839.83
木麻黄人工林	452	0.42	44	9.73	10.27	213.37	2.02
其他人工林	7235	6.66	1530	21.15	4.73	250.81	2.26
其他林地	176	0.16	13	7.40	13.51	161.56	1.91
居住用地	4126	3.80	1202	29.13	3.43	293.26	2.33
园地	8693	8.00	301	3.46	28.88	144.09	10.95
农用地	26651	24.54	829	3.11	32.15	110.58	3.60
其他用地	6478	5.96	590	9.11	10.98	158.43	83.24

村旁树则位于居住用地附近。人工林面积占总面积的 7.08%，包括木麻黄人工林和桉树等其他人工林，有 1574 个斑块，其中木麻黄人工林面积为 452 hm^2，主要位于沿海地区，用作沿海防护林。退化原始林面积为 6837hm^2，占景观总面积的 6.29%，主要分布在距离居民点较远、人为干扰相对较少的北部山区(吊罗山林区)。河流、湖泊、沙地等其他用地面积为 6478 hm^2，占总面积的 5.96%。原始林面积占总面积的 4.74%，为 5153hm^2，主要位于北部吊罗山林区高海拔地区，从斑块数(11)来看，原始林连片分布、相对集中。居住用地主要分布在东部城区和南部沿海地区，占景观总面积的 3.80%。退化林地的面积为 2358hm^2，占景观总面积的 2.17%，有 766 个斑块，主要是天然林开发后的弃荒地，散落在次生林周围。此外，未列入以上林地类型的其他林地面积为 176 hm^2，占景观总面积的 0.16%。

从景观要素斑块形状来看，各林地类型的平均斑块形状指数(MSI)排序为次生林 > 橡胶林 > 原始林 > 其他人工林 > 木麻黄人工林 > 退化原始林 > 其他林地 > 退化林地。由于次生林的树种组成主要是先锋树种，具有较强的扩散性，其形状指数最高，为 35.14。其次是橡胶林(19.42)，因其多分布在丘陵地区，地形因素使其形状趋于复杂。原始林(2.31)和人工林(2.26)的斑块形状比较接近，趋于相对规整，主要

原因是原始林多分布在高海拔、人类难以进入的地区，而人工林多位于易于收获的地区，人为干扰较大，形状较为规则。退化林地的形状指数为1.82，由于受次生林、园地的分割蚕食，使其形状趋于规整。非林地类型中，村旁树的形状最为复杂，其形状指数最高，为839.83，其次是河流、湖泊等其他用地。园地分布范围广，受地形影响，其形状也较为复杂。农用地和居住用地显然受地形制约和人为活动最频繁，由于多分布于丘陵和中部平原地区，其斑块形状复杂程度最低。

斑块边缘密度的大小反应景观中异质斑块之间物质、能量、物种及其他信息交换的潜力及相互影响的强度，但是由于景观要素的边缘密度既受景观要素斑块大小的影响，也受景观要素斑块边界形状的影响，所以不能直接反应景观要素斑块分化的具体细节。对比各景观要素类型的边缘密度得出，退化林地、居住用地、村旁树等受人为干扰较大、斑块数较多的景观类型的边缘密度远远大于原始林、退化原始林、次生林、橡胶林等分布相对集中的景观要素类型。其中退化林地的边缘密度最高，为341.38m/hm^2，而原始林的边缘密度最低，为38.39m/hm^2，这也反映了退化林地、居住用地、村旁树等人为景观具有更高的破碎化，原始林、退化原始林、次生林等自然景观的斑块边界更加规则，而橡胶林等半自然景观由于便于经营管理，人为活动使其形状趋于规则。

在景观要素破碎化程度方面，通过比较分析斑块密度(PD)和平均斑块面积(MPS)可以说明不同景观要素在景观空间结构中的作用和特点，可以反映某景观要素在景观中的斑块分化程度。由表4-3可见，各景观要素斑块密度和平均斑块面积均有较大差异，斑块分化程度较高。退化林地、居住用地和人工林的斑块密度相对较大、斑块规模较小，说明这些景观类型受人为活动影响较为频繁，其破碎化程度较高；其中退化林地的斑块密度最大，达到32.48个/100hm^2，这是由于退化林地散落于原始林、次生林之间，受到反复的人为干扰和农地、橡胶林的分割，其斑块连接度低。原始林、橡胶林、次生林和退化原始林的斑块密度分别为0.21个/100hm^2、0.70个/100hm^2、1.39个/100hm^{2}和1.61个/100hm^2，明显低于其他景观要素类型；尤其是原始林，其平均斑块面积达到468.43 hm^2。这是由于处于保护状态的原始林受人为干扰最小，同时原始林的稳定结构使其受到外界环境变化的影响较小，因而其破碎化程度最低。橡胶林尽管受到的人为干扰较大，但是由于水、肥等地力因素的限制，分布也相对集中。相比原始林，人类对次生林和退化原始林的木质和非木质林产品的利用较多，但是由于次生林的早期先锋

特性使其斑块面积不断扩大，退化原始林多分布在距离居民点较远的地方，因此次生林和退化原始林的破碎化程度较低。

4.3.2 景观格局总体特征分析

陵水黎族自治县森林景观总面积 108611hm^2，共有 6303 个斑块，平均斑块面积为 17.23 hm^2，斑块密度为 5.80 个/100hm^2，斑块形状指数为 86.82；景观多样性指数 SDI、均匀度指数 SEI 和优势度指数 D 分别为 1.86、0.70 和 0.80(见表 4-4)。

表 4-4 陵水黎族自治县森林景观格局总体特征(2008 年)

指标	面积 (hm^2)	斑块数 NP(n)	斑块密度 PD (个/100hm^2)	平均斑块面积 MPS (hm^2)	边缘密度 ED (m/hm^2)	平均斑块形状指数 MSI	SDI	SEI	D
特征值	108611	6303	5.80	17.23	131.67	86.82	1.86	0.7	0.80

森林景观格局随水热条件组合的差异，呈现有规律的地带性分布。从宏观上看，陵水黎族自治县地势北高南低、西高东低，从西北到东南依次可分为四大地貌结构带，即北部山区地带、西部丘陵地带、中部平原地带和东南沿海台地地带。这种地貌格局以及由此引起的水热再分配形成了陵水黎族自治县独特的森林景观格局：北部山区地带以原始林、次生林和退化林地为主，西部丘陵地带以橡胶林、次生林为主，中部平原地带多为农用地和园地，东南沿海台地地带以农用地和居住用地为主。陵水黎族自治县森林景观多样性指数、优势度指数较高，各景观要素类型的斑块面积和斑块数分布极不均衡；农用地和次生林的面积之和为 51415 hm^2，占景观总面积的 47.34%(见表 4-3)，可以看作研究区的主导景观类型；原始林、退化原始林和橡胶林在景观中占有较小的面积比例，但是斑块密度小、斑块规模大，分布集中，破碎化程度较低，而退化林地散落于原始林、次生林之间，受到反复人为干扰和农地、橡胶林的分割，其斑块连接度低、破碎化程度高；陵水黎族自治县整体景观以林地为基质，并与农用地、其他用地等斑块较小的景观要素类型相互交错分隔，居民点、园地等景观要素散布于其中的异质森林景观。

4.4 1991～2008 年森林景观格局动态

景观的动态变化是指区域景观嵌块体的结构和功能随时间而发生的变化。景观动态研究的目的是了解和掌握景观功能随景观结构变化而变化的过程和规律，采取科学有效的景观调控、管理措施提供科学依据。

4.4.1 景观要素组成及斑块特征变化

景观要素组成结构是指景观中各景观要素类型的相对数量关系。本章以各景观要素类型的类斑面积(CA)、面积比(PLAND)和斑块数(NP)来说明陵水黎族自治县1991 ~2008年间各景观要素组成结构的变化。

陵水黎族自治县景观总面积是108611hm^2，1991 ~2008年间除原始林外，各景观要素类型面积均有不同程度的变化，主要以园地、村旁树、居住用地和其他人工林的面积的增加和次生林、退化原始林、农用地和木麻黄人工林面积的减少为主(见表4-5和图4-1)。总体上看，天然林(包括原始林、退化原始林和次生林)面积比例在不断减少(由1991年的45.15%减少到1999年的37.81%到2008年的33.83%)，人工林(包括园地、橡胶、村旁树、木麻黄和其它人工林)面积比例在不断增加(由1991年的17.84%增加到1999年的21.25%到2008年的29.52%)。

表4-5　陵水黎族自治县1991 ~2008年森林景观要素类型面积变化

类型	类斑面积CA(hm^2)			面积比PLAND%			面积变化%		
	1991	1999	2008	1991	1999	2008	1991 ~1999	1999 ~2008	1991 ~2008
原始林	5153	5153	5153	4.74	4.74	4.74	0.00	0.00	0.00
退化原始林	9882	8124	6837	9.10	7.48	6.29	-17.79	-15.84	-30.82
次生林	34004	27790	24764	31.31	25.59	22.80	-18.28	-10.89	-27.17
退化林地	954	1859	2358	0.88	1.71	2.17	94.95	26.87	147.34
橡胶林	8200	9473	8324	7.55	8.72	7.66	15.52	-12.13	1.51
村旁树	2283	7125	7365	2.10	6.56	6.78	212.14	3.37	222.65
木麻黄人工林	1846	463	452	1.70	0.43	0.42	-74.91	-2.39	-75.51
其他人工林	5505	4211	7235	5.07	3.88	6.66	-23.50	71.80	31.43
其他林地	735	1196	176	0.68	1.10	0.16	62.65	-85.31	-76.11
居住用地	2442	3057	4126	2.25	2.81	3.80	25.20	34.98	69.00
园地	1553	1798	8693	1.43	1.66	8.00	15.74	383.60	459.74
农用地	29614	31365	26651	27.27	28.88	24.54	5.91	-15.03	-10.01
其他用地	6441	6999	6478	5.93	6.44	5.96	8.66	-7.45	0.57
总	108611	108611	108611	100	100	100	—	—	—

从1991 ~2008年间单一景观要素类型的面积变化来看，原始林面积保持稳定。次生林面积从1991年的34004 hm^{2}减少到2008年的24764hm^2，减少9240 hm^2，占景观总面积的比例相应降低了8.51%，是面积变化最大的景观要素类型。其次是退化原始林，面积减少3045hm^2，面积比也相应减少2.81%。农用地、木麻黄人工林和其他林地的面积分别减少2963 hm^2、1394 hm^{2}和559 hm^2。面积增加最多的景

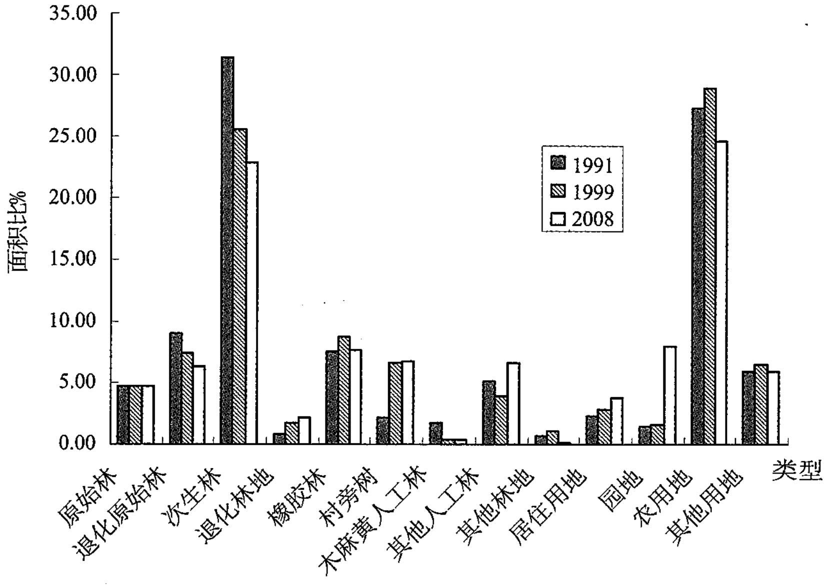

图 4-1 陵水黎族自治县 1991 ~ 2008 年森林景观要素类型面积比

观要素类型是园地，从 1553 hm^2增加到 8693 hm^2，面积比增加 6.57%；其次是村旁树，增加的面积为 5083 hm^2。其他人工林、居住用地和退化林地的面积也有不同程度的增加，面积比分别提高了 1.59%、1.55% 和 1.29%。橡胶林面积略有增加，面积比提高了 0.11%，而其他用地的面积增加最少(37 hm^2)。

从不同时期各景观要素的面积变化来看，1991 ~ 2008 年间面积变化幅度最大的是园地，17 年间面积持续增加，增加的面积是 1991 年的 4.60 倍，但是这种变化主要发生在 1999 ~ 2008 年间；其次是村旁树，17 年间增加的面积为 1991 年的 2.23 倍，这种增加主要发生在 1991 ~ 1999 年间；退化林地面积增加幅度也较大，为 147.34%，其中 1991 ~ 1999 年间和 1999 ~ 2008 年间面积增加幅度分别为 94.95% 和 26.87%；1991 ~ 1999 年和 1999 ~ 2008 年两个时期面积持续增加的景观要素类型还包括居住用地，只是后一时期面积增加幅度略大于前一时期。1991 ~ 2008 年间，面积持续减少的景观要素类型有次生林、退化原始林和木麻黄人工林，并且面积的减少主要发生在 1991 ~ 1999 年间。其中次生林和木麻黄人工林在两个时期的面积变化差异较为显著，1991 ~ 1999 年间减少的面积明显大于 1999 ~ 2008 年间。次生林和退化原始林面积的减少也说明天然林面积在 1991 ~ 2008 年间呈减少趋势。橡胶林和其他用地的面积变化趋势是先增加后减少，但是前一时期增加的面积大于

后一时期减少的面积，造成这两种类型1991～2008年间面积略有增加。其他林地、农用地面积先增加后减少，并且1999～2008年间减少的面积大于1991～1999年间增加的面积。其他人工林的面积变化与其他景观要素类型不同，1999～2008年间增加的面积(3024 hm^2)明显大于1991～1999年间减少的面积(1294 hm^2)，促使其他人工林2008年的面积大于1991年。

陵水黎族自治县各景观要素类型1991～2008年间斑块数变化见表4-6和图4-2。斑块总数从1991年的1961增加到2008年的6303，其中原始林斑块数保持不变，木麻黄人工林和其他林地的斑块数有所减少，而其他景观要素类型的斑块数均有不同程度的增加。1991年各景观要素斑块数差异明显，农用地斑块数最多，为563，占景观斑块总数的28.71%，其次是居住用地，斑块比例为26.57%；1999年景观斑块数显著增加，村旁树的斑块数最多，其次是其他人工林，斑块比例分别为23.89%和20.56%；相比1999年，2008年景观斑块总数略有减少，斑块数最多的景观要素类型为其他人工林。从不同时期的斑块数变化来看，1991～2008年景观斑块数的增加集中在1991～1999年间。其中原始林斑块数保持稳定，退化原始林、次生林、退化林地、其他人工林和居住用地的斑块数在两个时期均有增加，橡胶林、其他林地、农用地和其他用地的斑块数先增加后减少，园地的斑块数先减少后增加，木麻黄人工林的斑块数持续减少。

表4-6　陵水黎族自治县1991～2008年森林景观要素类型斑块数变化

类型	类斑面积 CA(hm^2)			面积比 PLAND%			面积变化%		
	1991	1999	2008	1991	1999	2008	1991～1999	1999～2008	1991～2008
原始林	11	11	11	0.56	0.15	0.17	0	0	0
退化原始林	30	82	110	1.53	1.12	1.75	52	28	80
次生林	101	208	344	5.15	2.85	5.46	107	136	243
退化林地	80	629	766	4.08	8.62	12.15	549	137	686
橡胶林	16	105	58	0.82	1.44	0.92	89	-47	42
村旁树	146	1744	505	7.45	23.89	8.01	1598	-1239	359
木麻黄人工林	64	61	44	3.26	0.84	0.70	-3	-17	-20
其他人工林	118	1501	1530	6.02	20.56	24.27	1383	29	1412
其他林地	21	34	13	1.07	0.47	0.21	13	-21	-8
居住用地	521	914	1202	26.57	12.52	19.07	393	288	681
园地	134	132	301	6.83	1.81	4.78	-2	169	167
农用地	563	1212	829	28.71	16.60	13.15	649	-383	266
其他用地	156	668	590	7.96	9.15	9.36	512	-78	434
总	1961	7301	6303		100		5340	-898	4342

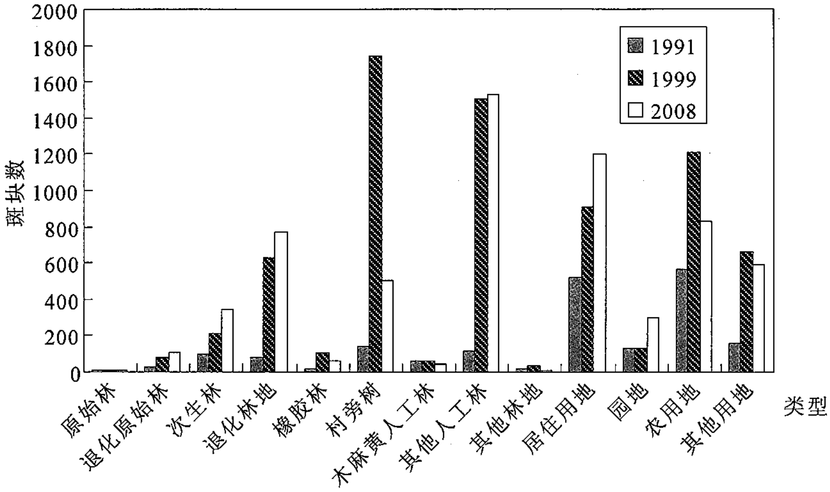

图 4-2 陵水黎族自治县 1991 ~ 2008 年森林景观要素类型斑块数变化

4.4.2 景观要素类型异质性变化

分别比较陵水黎族自治县 1991、1999 和 2008 年各景观要素类型的斑块密度(PD)和边缘密度(ED)(见表 4-7)，分析景观要素类型的异质性变化。

表 4-7 陵水黎族自治县 1991 ~ 2008 年森林景观要素类型斑块密度和边缘密度变化

景观要素类型	斑块密度 PD(个/100hm^2)			边缘密度 ED(m/hm^2)		
	1991	1999	2008	1991	1999	2008
原始林	0. 21	0. 21	0. 21	38. 39	38. 39	38. 39
退化原始林	0. 30	1. 01	1. 61	36. 64	49. 58	57. 52
次生林	0. 30	0. 75	1. 39	38. 91	52. 67	68. 23
退化林地	8. 39	33. 84	32. 48	141. 70	285. 40	341. 38
橡胶林	0. 20	1. 11	0. 70	54. 46	109. 55	104. 87
村旁树	6. 40	24. 48	6. 86	180. 80	327. 09	265. 76
木麻黄人工林	3. 47	13. 17	9. 73	127. 66	227. 69	213. 37
其他人工林	2. 14	35. 64	21. 15	119. 61	293. 79	250. 81
其他林地	2. 86	2. 84	7. 40	150. 68	165. 34	161. 56
居住用地	21. 34	29. 90	29. 13	200. 27	270. 10	293. 26
园地	8. 63	7. 34	3. 46	168. 04	191. 55	144. 09
农用地	1. 90	3. 86	3. 11	82. 31	133. 72	110. 58
其他用地	2. 42	9. 54	9. 11	152. 43	209. 36	158. 43

1991 年，居住用地的斑块密度指数最大(21.34 个/100 hm^2)，边缘密度也最大(200.27m/ hm^2)，多以小斑块相对分散的分布格局组成，破碎化程度较高。橡胶林的斑块密度指数最小(0.20 个/100 hm^2)，说明 1991 年橡胶的种植范围较小，只是集中在国有或集体农场等区域。园地、退化林地、村旁树的斑块密度指数较高，分别为 8.63 个/100 hm^2、8.39 个/100 hm^2、6.40 个/100 hm^2，由于这类景观要素受人为干扰较大，空间扩展能力很强，呈镶嵌状分布于其他景观要素类型之间，因此其破碎化程度较高。原始林、退化原始林、次生林的斑块密度指数较低，边缘密度指数也较小，斑块形状较为规则，除了分布相对集中，还与受保护的程度有关。总的来看，居住用地等人为景观的斑块密度和边缘密度最大，园地、退化林地等空间扩展能力较强的半自然景观次之，退化原始林、次生林、原始林等自然景观的斑块密度和边缘密度最小，而橡胶林、农用地等半自然景观由于自然条件的限制，斑块较为规则、分布集中，其斑块密度指数和边缘密度指数也相对较小。

1999 年各景观要素类型的斑块密度指数大小排序与 1991 年类似，并且除原始林、园地外，其他类型的斑块密度均有增长，尤其是其他人工林，从 1991 年的 2.14 个/100 hm^2 增加到 1999 年的 35.64 个/100 hm^2，其次是退化林地，从 1991 年的 8.39 个/100 hm^2 增加到 1999 年的 33.84 个/100 hm^2，说明人为活动对其他人工林和退化林地的影响显著增强，造成其他人工林和退化林地进一步破碎。村旁树是 1999 年边缘密度最大的景观要素类型，其斑块密度变化也比较明显，但是村旁树的破碎化与其分布特征有关，结合前面的面积变化分析，可以看出研究区居民对种植村旁树的积极性提高。退化原始林、次生林在面积减少的同时，斑块密度增大，边缘密度略有增加，说明这两类景观要素受人为干扰的强度增大，斑块形状趋于复杂，破碎化程度加大。

1991 ~2008 年间，斑块密度始终增大的类型有退化原始林、次生林，由于其面积呈减少趋势，进一步说明这两种类型的破碎化越来越严重；其他类型除原始林保持稳定外，斑块密度指数均呈现先增大后减小的变化，只是变化幅度有差异，反映了人为活动对研究区森林景观的影响程度也是先增大后减小。从各景观要素类型边缘密度的变化来看，原始林边缘密度保持不变，退化原始林、次生林、退化林地、橡胶林和居住用地的边缘密度增加，斑块形状的不规则程度加大，而村旁树、木麻黄人工林、其他人工林、其他林地、园地、农用地和其他用地的边缘密度在 1991 ~1999 年间增加，在 1999 ~2008 年间减小，说明各类型斑块

形状由不规则向规则变化。

4.4.3 景观总体特征变化

陵水黎族自治县1991～2008年森林景观总体特征变化见表4-8。1991～1999年，景观斑块数增加了5340个，斑块密度变化显著，由1.81个/100hm²提高到6.72个/100hm²，边缘密度由74.13m/hm²降低为131.94 m/hm²，景观多样性指数和均与度指数均有所提高，优势度下降。1999～2008年，景观斑块数减少了898个，斑块密度也相应降低，而边缘密度基本稳定，景观多样性指数和均匀度指数仍有所提高，优势度指数持续降低。从不同时间林业用地的面积变化来看，1991、1999和2008年的林业用地面积占景观总面积的比例分别为61.02%、53.65%和50.91%，呈下降趋势，说明1991～2008年间，陵水黎族自治县的林业用地面积逐年递减，林业用地逐渐被园地、居住用地等非林业用地所替代。分析以上指数的变化可以得出：1991～2008年间，陵水黎族自治县各景观要素类型不断被分割，斑块形状日趋规整，斑块总数显著增加，导致景观日趋破碎。与此同时，景观多样性提高，优势度下降，由于景观要素类型的数量和各要素类型间的面积分配比例决定了景观多样性指数的大小，因此景观多样性指数和均匀度指数提高也说明所划分的13个景观要素类型之间的面积分配差异逐渐减小，这与不同时期次生林和农用地在景观中优势地位的下降是一致的(详见附录5)。

表4-8 陵水黎族自治县1991～2008年森林景观格局总体特征变化

时间(年)	面积(hm²)	斑块数NP(n)	斑块密度PD(个/100hm²)	边缘密度ED(m/hm²)	多样性指数SDI	均匀度指数SEI	优势度指数D	林业用地	
								面积(hm²)	比例(%)
1991	108611	1961	1.81	74.13	1.16	0.45	1.42	66279	61.02
1999	108611	7301	6.72	131.99	1.55	0.59	1.08	58268	53.65
2008	108611	6303	5.80	131.67	1.86	0.70	0.80	55298	50.91

4.5 森林景观动态预测

森林景观恢复的实施是一个长达十年甚至几十年的长期过程，除了应对巨大的社会、经济、文化和技术挑战，了解、掌握森林景观自身的变化也是森林景观恢复成功的主要因素。本章在分析研究区森林景观格局现状和动态变化的基础上，通过建立森林景观动态模型，抽象概括研究区景观动态变化的整体特征，揭示变化过程和整体发展趋势，为进一步分析动态变化的成因机制，制定森林景观恢复规划提供依据。

采用 Markov 模型，依据 1999 ~2008 年各景观要素间转移概率矩阵（见表 4-9），预测陵水黎族自治县森林景观结构总体变化趋势。预测结果见表 4-10 和图 4-3。

表 4-9　陵水黎族自治县 1999 ~ 2008 年景观要素转移概率矩阵①

1999	2008												
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL
PF	100.00	-	-	-	-	-	-	-	-	-	-	-	-
DPF	-	84.16	11.39	1.24	0.05	-	-	-	-	-	2.79	0.02	0.35
SF	-	-	85.78	3.62	1.23	0.71	-	3.52	-	0.17	2.57	1.95	0.44
DFL	-	-	-	9.58	13.54	1.82	0.29	56.43	0.11	0.81	10.19	4.82	2.40
RP	-	-	-	4.85	63.02	2.41	-	7.44	0.42	0.85	12.73	7.01	1.26
TaV	-	-	-	0.37	0.55	39.60	0.25	6.94	0.15	11.03	10.90	26.66	3.57
CeP	-	-	-	-	-	1.33	11.38	0.77	-	4.25	0.37	53.44	28.46
OP	-	-	-	3.18	8.30	12.43	1.49	23.72	0.90	3.54	15.92	23.01	7.50
OFL	-	-	-	-	6.42	4.44	-	7.62	1.74	2.39	25.76	51.04	0.58
RQL	-	-	-	0.93	2.47	19.32	0.25	3.09	0.01	62.17	3.22	7.16	1.39
GP	-	-	-	0.02	8.16	9.26	0.01	6.01	-	1.57	30.10	43.69	1.18
AL	-	-	-	1.11	2.80	8.05	0.28	6.62	0.16	3.00	11.15	61.73	5.10
OL	-	-	-	1.08	2.71	3.14	3.10	9.11	0.18	1.87	6.65	18.01	54.17

①:PF - 原始林,DPF - 退化原始林,SF - 次生林,DFL - 退化林地,RP - 橡胶林,TaV - 村旁树,CeP - 木麻黄人工林,OP - 其他人工林,OFL - 其他林地,RQL - 居住用地,GP - 园地,AL - 农用地,OL - 其他用地。

表 4-10　陵水黎族自治县不同景观要素类型各分期占有率（%）现状与预测

类型	各分期占有率（%）									
	2008	2017	2026	2035	2044	2053	2062	2071	2080	2089
原始林	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74
退化原始林	6.29	5.30	4.46	3.75	3.16	2.66	2.24	1.88	1.58	1.33
次生林	22.80	20.28	18.00	15.95	14.11	12.46	10.99	9.68	8.52	7.49
退化林地	2.17	2.09	2.01	1.95	1.89	1.84	1.79	1.75	1.71	1.68
橡胶林	7.66	7.60	7.73	7.88	8.02	8.15	8.28	8.38	8.48	8.57
村旁树	6.78	7.55	8.20	8.72	9.13	9.49	9.79	10.05	10.28	10.48
木麻黄人工林	0.42	0.43	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52
其他人工林	6.66	7.43	7.63	7.73	7.81	7.88	7.94	8.00	8.05	8.09
其他林地	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
居住用地	3.80	4.46	5.01	5.46	5.85	6.17	6.44	6.68	6.88	7.06
园地	8.00	9.46	10.03	10.37	10.63	10.86	11.06	11.23	11.39	11.52
农用地	24.54	24.72	25.82	26.97	28.02	28.94	29.75	30.47	31.10	31.65
其他用地	5.96	5.76	5.76	5.86	6.00	6.15	6.30	6.44	6.56	6.68

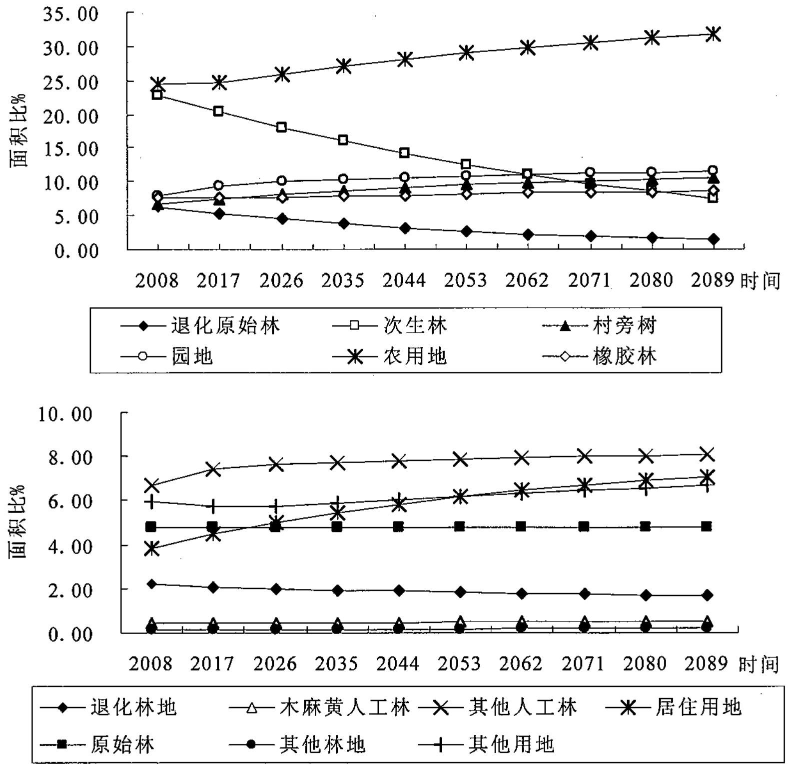

图 4-3 陵水黎族自治县不同景观要素类型各分期占有率现状与预测比较图

预测结果表明，若研究区继续保持 1999 ~ 2008 年的发展趋势，今后几十年的景观格局变化为：森林等自然景观逐渐减少，农用地等半自然景观和居住用地等人为景观逐渐增加，景观格局朝着生态环境恶劣的方向发展。预计到 2089 年研究区退化原始林和次生林分别减少至 1.33%、7.49%，而农用地和居住用地则分别增加至 32.65%、7.06%，这四类是变化比较明显的景观要素类型。其他类型如村旁树、木麻黄和其他人工林、园地和其他林地则呈现缓慢增加的趋势，橡胶林和其他用地会先减少后增加，但是变化幅度很小，基本稳定。总的来看，这种发展趋势明显与研究区的社会经济发展不符，尤其是退化原始林、次生林等天然林急剧减少和农用地、居住用地的无限扩张，因此必须对目前的景观格局进行适当干预，促使土地利用向良性方向转移。

4.6 小 结

本章以陵水黎族自治县为例，从景观要素分类、数据获取与处理、

景观格局与动态分析等方面，研究了区域水平景观格局分析技术。

(1)从 FLR 的角度，建立了适用于研究区森林景观格局分析的森林景观要素分类系统：原始林、退化原始林、次生林、退化林地、橡胶林、村旁树、木麻黄人工林、其他人工林、其他林地、居住用地、园地、农用地和其他用地。

(2)陵水黎族自治县景观多样性指数、优势度指数较高，各景观要素类型的面积和斑块分布极不均衡。天然林(包括原始林、退化原始林和次生林)面积比例为 33.83%，其中次生林面积为 24764hm^2，占景观总面积的 22.80%，主要位于北部浅山地区和整个丘陵地区；原始林和退化原始林在景观中占有较小面积比例，分别为 4.74%、6.29%，但是斑块密度小、斑块规模大，集中分布于距离居民点较远、人为干扰相对较少的北部吊罗山林区，破碎化程度较低。退化林地面积比例为 2.17%，散落于原始林、次生林周围，受到反复人为干扰和农地、橡胶林的分割，其斑块连接度低、破碎化程度高。

(3)1991 ~2008 年间除原始林外，各景观要素类型面积均有不同程度的变化，主要以园地、村旁树、居住用地和其他人工林的面积的增加和次生林、退化原始林、农用地和木麻黄人工林面积的减少为主。总体上看，天然林(包括原始林、退化原始林和次生林)面积比例在不断减少(由 1991 年的 45.15% 减少到 1999 年的 37.81% 到 2008 年的 33.83%)，人工林(包括园地、橡胶、村旁树、木麻黄和其它人工林)面积比例在不断增加(由 1991 年的 17.84% 增加到 1999 年的 21.25% 到 2008 年的 29.52%)。各景观要素类型不断被分割，斑块形状日趋规整，斑块总数显著增加，导致景观日趋破碎。与此同时，景观多样性提高，优势度下降，所划分的 13 个景观要素类型之间的面积分配差异逐渐减小。

(4)景观动态预测结果表明：森林等自然景观逐渐减少，农用地等半自然景观和居住用地等人为景观逐渐增加，景观格局朝着生态环境恶劣的方向发展。预计到 2089 年研究区退化原始林和次生林分别减少至 1.33%、7.49%，而农用地和居住用地则分别增加至 31.65%、7.06%。其他类型如村旁树、木麻黄和其他人工林、园地和其他林地则呈现缓慢增加的趋势，橡胶林和其他用地会先减少后增加，但是变化幅度很小，基本稳定。这种发展趋势明显与研究区的社会经济发展不符，尤其是退化原始林、次生林等天然林急剧减少和居住用地的无限扩张，因此必须对目前的景观格局进行适当干预，促使土地利用向良性方向发展。

第五章 社区水平景观格局分析

本章以大敢 FLR 示范区为例，从景观要素分类、数据获取与处理、景观格局与动态分析等方面，研究社区水平景观格局分析技术。

5.1 景观要素分类

根据第四章 4.1 基于 FLR 的景观要素分类结果，结合大敢村的土地利用现状，从森林恢复与重建的角度，将大敢 FLR 示范区森林景观分为 8 类：退化原始林、次生林、退化林地、人工林、旱地、水田、居民点和水库。

5.2 数据获取与处理

5.2.1 现有资料的收集

收集覆盖大敢 FLR 示范区的两期遥感影像：1999 年获取的航空影像和 2008 年 12 月 9 日获取的 World-view 影像。收集群英乡“十一五”发展规划与计划、大敢村基本情况报表等文本资料。

5.2.2 参与式区划与调查

以示范区 1∶10000 地形图为参照，对两期遥感影像进行校正，结合动态分类、多源信息融合和目视解译，以基于 FLR 的景观要素分类为参考，进行室内森林景观分类信息的初步提取。与区域水平景观格局分析不同，社区水平是落实具体恢复措施的尺度，景观格局分析所需信息更为详细，要求具体到不同景观要素类型、不同权属，这些信息无法利用遥感手段得到，因此需要在遥感信息提取的基础上，对示范区进行区划、调查。

区划调查采用参与式，即调查小组成员至少包括一名当地居民，并在调查过程中与村民进行访谈，获取每个斑块的土地利用现状、权属、土地利用历史和未来可能的利用方式等信息。区划调查时间主要集中在 2008 年 11 ~12 月，2009 年 3 ~4 月。通过参与式调查，确定不同权属、不同景观要素类型和不同经营历史的斑块边界，每个斑块的具体信息包括：地貌、坡位、坡度、利用现状、群落结构、植被盖度、林分长势、权属、经营历史、管理投入、转换或开发时限、潜在驱动因素、未来可

能的利用方式等。在 GIS 工具支持下，初步形成示范区不同时期景观镶嵌图，通过村民大会、半结构访谈等参与式农村评估(PRA)的工具，将调查、区划结果和景观镶嵌图反馈给村民，与村民不断交流，最终形成 1990 年、1999 年和 2009 年示范区森林景观镶嵌图(详见附录 6)。分析景观格局时，忽略权属的不同，以景观要素类型作为划分斑块边界的依据；制定立地水平恢复策略时，则以权属和景观要素类型为斑块划分的依据。

5.3　大敢 FLR 示范区森林景观格局现状

5.3.1　景观要素组成及斑块特征

分别统计大敢 FLR 示范区 8 个景观要素类型的类斑面积(CA)、面积比(PLAND)、斑块数(NP)、斑块密度(PD)、平均斑块面积(MPS)、边缘密度(ED)和平均斑块形状指数(AWMSI)(见表 5-1)，以此说明示范区 2009 年景观要素组成及斑块特征。

示范区位于陵水黎族自治县西北部的群英乡，总面积 399.48 hm^2，由退化原始林、次生林、退化林地、人工林、旱地、水田、居民点和水库构成。

从面积和斑块数来看，人工林面积最大，为 240.30hm^2，占景观总面积的 60.15%，有 14 个斑块；其次是次生林，面积为 47.55 hm^2，斑块数为 43，退化原始林面积列第 3，为 42.06 hm^2，由 6 个斑块构成，次生林和退化原始林分别占总面积的 11.90% 和 10.53%；水田面积 26.82 hm^2，面积比为 6.71%；退化林地在示范区也有较大分布，面积 18.11 hm^2，占景观总面积的 4.53%；旱地、居民点、水库占景观总面积的比例相对较小，面积分别为 15.32 hm^2、8.32 hm^2和 1.00 hm^2，旱地的斑块数明显多于居民点和水库。

从分布来看(详见附录 6)，人工林几乎填充于示范区的整个空间，特别是中北部地区。次生林除示范区靠近小流域的西南部有集中分布外，其他大都散布于人工林中间，形成人工林—次生林的典型镶嵌格局。而退化原始林则主要分布于以前尚未开发过的山顶区域，如示范区南部和东南部，由于某些限制性因子，如位置偏远、交通不便，距水源较远、水土匹配较差，石块较多、土壤贫瘠等而未被开发。退化林地因主要来源于自然景观开发后的荒弃，大多分布于示范区的南部地区，镶嵌于退化原始林斑块中。

表 5-1　大敢 FLR 示范区 2009 年森林景观要素特征

景观要素类型	类斑面积 CA(hm^2)	面积比 PLAND%	斑块数 NP(n)	斑块密度 PD (个/100hm^2)	平均斑块面积 MPS (hm^2)	边缘密度 ED (m/hm^2)	平均斑块形状指数 MSI
退化原始林	42.06	10.53	6	14.27	7.01	320.19	2.21
次生林	47.55	11.90	43	90.43	1.11	519.63	1.68
退化林地	18.11	4.53	37	204.31	0.49	684.69	1.44
人工林	240.30	60.15	14	5.83	17.16	222.24	1.94
旱地	15.32	3.83	30	195.82	0.51	671.17	1.45
水田	26.82	6.71	21	78.30	1.28	511.79	1.82
居民点	8.32	2.08	3	36.06	2.77	317.70	1.63
水库	1.00	0.25	5	500.00	0.20	843.99	1.27

从破碎化程度来看，退化林地和旱地受人为活动最为频繁，破碎化程度最高，表现为平均斑块面积较小、斑块密度和边界密度较大，其中退化林地的斑块密度指数为 204.31 个/100hm^2，平均斑块面积为 0.49hm^2，这与退化林地和旱地在其他景观要素类型间的镶嵌分布有关；次生林在退化林地和旱地的分割下，平均斑块面积 1.11hm^2，破碎化严重，边界较不规则；退化原始林斑块密度指数为 14.27 个/100hm^2，平均斑块面积 7.01hm^2，受人为干扰相对较少，分布集中；人工林的斑块密度和边界密度最小，平均斑块面积为 17.16hm^2，表明人工林的破碎化程度低，但是这并不说明人工林受人为干扰最小，而是因为槟榔、橡胶等人工林在示范区多为大面积连片种植。

5.3.2　景观格局总体特征分析

表 5-2　大敢 FLR 示范区景观格局总体特征(2009 年)

指标	面积 (hm^2)	斑块数 NP(n)	斑块密度 PD (个/100hm^2)	平均斑块面积 MPS (hm^2)	边缘密度 ED (m/hm^2)	平均斑块形状指数 MSI	SDI	SEI	D
特征值	399.48	159	39.80	2.51	329.12	1.63	1.35	0.65	0.73

从表 5-2 可以看出，大敢 FLR 示范区景观总面积 399.48hm^2，共有 159 个斑块，景观多样性指数 SDI、均匀度指数 SEI 和优势度指数 D 分别为 1.35、0.65 和 0.73，平均斑块面积为 2.51hm^2。斑块密度、边缘密度分别为 39.80/100hm^2和 329.12 m/hm^2。综合各景观要素类型的斑块特征分析可见，示范区总体上以人工林景观为主体，其他景观要素类型镶嵌分布的格局。其中人工林分布于示范区中北部，可以看作景观的

基质，次生林、退化原始林也占有一定比例，位于南部海拔较高、人为活动较少的山顶，退化林地和旱地则镶嵌于人工林、退化原始林和次生林之间，示范区大小水库(水塘)有5处，水田沿河溪两岸、水库周边分布，居民点则位于周山包围的盆地中，水田、居民点的分布相对集中。同时景观破碎化严重，尤其是退化原始林、次生林和退化林地斑块。由示范区景观镶嵌图(详见附录6)可以看出，人工林景观在示范区总体格局中占主导地位，并且占据了河流两岸、水库周边具有重要生态意义的立地，而退化原始林等具有重要生物多样性的景观要素类型只在南部、东部山顶、人为活动难以到达的区域有所分布，景观异质性相对较低。因此，示范区景观格局存在一定问题，需要仅一步分析，并加以调整，以充分发挥各景观要素类型的生态功能和社会经济功能。

5.4　1990～2009年大敢村森林景观格局动态

5.4.1　景观要素组成及斑块特征变化

从景观要素类型的基本信息来看(表5-3和图5-1)，1990～2009年间示范区的景观格局变化主要体现在旱地、退化原始林的减少和人工林的增加上，其中退化原始林损失、人工林扩张主要发生在1990～1999年间，而旱地减少、人工林增加主要出现在1999～2009年期间。19年间，人工林是变化最大的景观要素类型，从1990年到2009年示范区共增加人工林面积208.88hm^2，比例增加52.28%，并且这一变化主要发生在1999～2009年间，10年间增加的面积比例达38.23%，人工林的急剧增加说明人为活动对景观的干扰逐渐增大。退化原始林由1990年的97.64 hm^{2}降低为2009年的42.06 hm^2，面积比例减少13.91%。与人工林的变化不同，两时段退化原始林减少的面积相近，分别为29.23 hm^{2}和26.36 hm^2。旱地面积由1990年的194.17 hm^2，减少为2009年的15.32 hm^2，这种减少主要发生在1999～2009年间，减少面积157.52 hm^2，比例减少39.44%。不同时期退化原始林、旱地的减少和人工林的增加，是否说明这三者之间发生了相互转化，还有待进一步的分析，但是可以得出示范区居民在调整土地利用方式时，是以经济收益为主要依据。次生林和退化林地呈现相同的变化趋势，1990～2009年间次生林和退化林地总体呈增加趋势，分别由1990年的34.42 hm^{2}和5.68 hm^2，增加为47.55 hm^{2}和18.11 hm^2，但是面积的增加发生在1999～2009年间。而其他景观要素类型，水田、居民点和水库面积

未发生变化，这由研究区地形、气候等自然因子决定。造成以上变化主要是受当地人民生产生活方式的影响，在1999年以前，发展橡胶等人工林开始成为居民经济收入的新来源，同时种植木薯等农作物和荔枝、杧果等经济林仍然是多数居民的主要经济来源，刀耕火种、毁林开荒导致研究区退化原始林、旱地斑块大幅减少，次生林、退化林地也得到开发，而人工林斑块面积大幅增加；1999年之后，由于木薯等农作物价格下降、橡胶、槟榔等林产品价格的大幅上涨，发展槟榔、橡胶等人工林成为当地居民的主要生产方式，一方面促使居民进一步开发退化原始林，另一方面导致居民放弃地力差、产量低的旱地，形成退化原始林持续减少、旱地面积急剧缩小的变化趋势，同时部分荒弃旱地演化为次生林、退化林地，造成1999 ~2009年间次生林、退化林地面积增加。引起景观变化的具体原因，还需要进一步的驱动力分析。

表5-3 大敢FLR示范区1990 ~ 2009年森林景观要素类型面积变化

类型	类斑面积 CA(hm^2)			面积比 PLAND%			面积变化%		
	1990	1999	2009	1990	1999	2009	1990 ~ 1999	1999 ~ 2009	1990 ~ 2009
退化原始林	97.64	68.42	42.06	24.44	17.13	10.53	-7.31	-6.6	-13.91
次生林	34.42	29.83	47.55	8.62	7.47	11.90	-1.15	4.43	3.28
退化林地	5.68	4.67	18.11	1.42	1.17	4.53	-0.25	3.36	3.11
人工林	31.42	87.57	240.3	7.87	21.92	60.15	14.05	38.23	52.28
旱地	194.17	172.84	15.32	48.61	43.27	3.83	-5.34	-39.44	-44.78
水田	26.82	26.82	26.82	6.71	6.71	6.71	0	0	0
居民点	8.32	8.32	8.32	2.08	2.08	2.08	0	0	0
水库	1	1	1	0.25	0.25	0.25	0	0	0
总	399.48	399.48	399.48	100	100	100	—	—	—

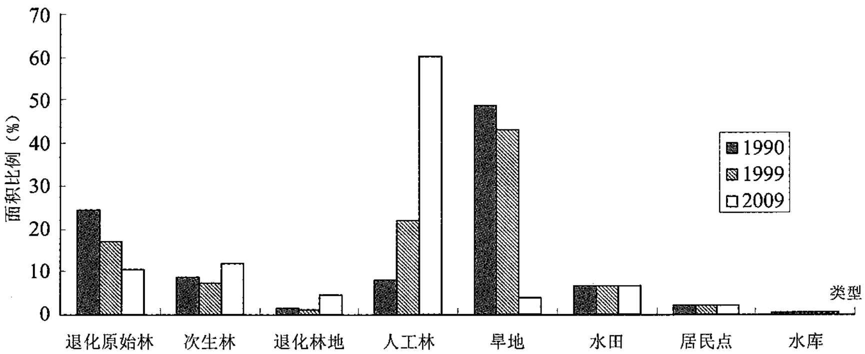

图5-1 大敢FLR示范区1990 ~ 2009年森林景观要素类型面积变化

大敢 FLR 示范区各景观要素类型 1990 ~ 2009 年间斑块数的变化主要体现在退化林地、次生林斑块的增加和人工林斑块的减少上，其中 1991 ~ 1999 年间斑块总数的增加体现为旱地和人工林斑块的增加，而退化林地、次生林斑块的增加和人工林、旱地斑块的减少发生在1999 ~ 2009 年间(见表 5-4 和图 5-2)。

表 5-4　大敢 FLR 示范区 1990 ~ 2009 年景观要素类型斑块数变化

类型	斑块数(n)			斑块数比例%			斑块数变化(N)		
	1990	1999	2009	1990	1999	2009	1990 ~ 1999	1999 ~ 2009	1990 ~ 2009
退化原始林	9	8	6	7.26	4.94	3.77	-1	-2	-3
次生林	29	28	43	23.39	17.28	27.04	-1	15	14
退化林地	8	10	37	6.45	6.17	23.27	2	27	29
人工林	24	36	14	19.35	22.22	8.81	12	-22	-10
旱地	25	51	30	20.16	31.48	18.87	26	-21	5
水田	21	21	21	16.94	12.96	13.21	0	0	0
居民点	3	3	3	2.42	1.85	1.89	0	0	0
水库	5	5	5	4.03	3.09	3.14	0	0	0
总	124	162	159	100	38	-3	35	—	—

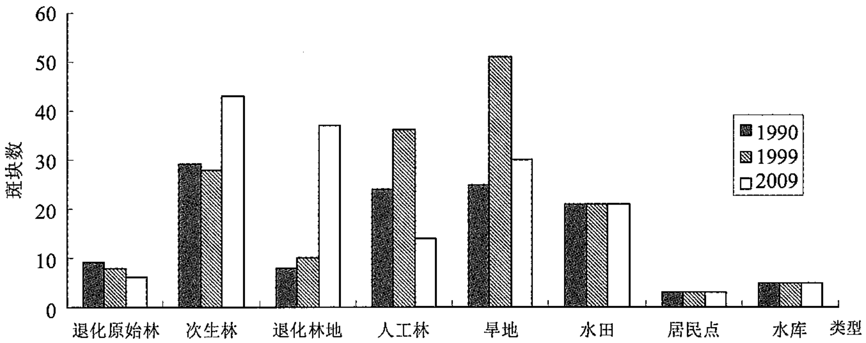

图 5-2　大敢 FLR 示范区 1990 ~ 2009 年景观要素类型斑块数变化

1990 年各景观要素斑块数差异不明显，尤其是次生林、旱地、人工林和水田，斑块数相近，分别为 29、25、24 和 21，退化原始林和退化林地的斑块数相近。1999 年景观斑块总数显著增加，变化最明显的类型是旱地，从 1990 年的 25 增加到 1999 年的 51，成为 1999 年斑块最多的类型，斑块数比例达 31.48%；人工林和退化林地斑块也有不同程度的增加；退化原始林和次生林分别减少了 1 个斑块。相比 1999 年，2009 年示范区景观斑块略有减少，次生林斑

块最多，为43，退化林地的斑块增加幅度最大，10年间增加27个斑块，而人工林和旱地在1999~2009年斑块数分别减少22、21。从不同时期的斑块数变化来看，1991~2009年景观斑块数的增加集中在1990~1999年间。退化林地斑块数在两个时期均有增加，人工林和旱地斑块先增加后减少，次生林的斑块先减少后增加，水田、居民点和水库斑块保持不变。

5.4.2 景观要素类型异质性变化

通过比较示范区各景观要素类型的斑块密度（PD）和边缘密度（ED）（见表5-5和图5-3），说明景观要素类型的异质性变化。1990 ~2009年间，各景观要素类型的斑块密度和边缘密度呈现相同的变化趋势，其中退化原始林、旱地的斑块密度和边缘密度在研究时期均有增加，以2009年最高，尤其是旱地的边缘密度在1999 ~2009年间增加显著，这表明退化原始林和旱地受到的人为干扰越来越频繁，斑块边越来越不规则，破碎化程度逐渐增大，与退化原始林的集中分布不同，旱地相对分散、其边界受相邻斑块的影响，如人工林和次生林对旱地斑块的分割。人工林的斑块密度和边缘密度保持下降趋势，平均斑块面积逐渐增大，斑块边界趋向于规则化、破碎化程度降低，但这并不表明人工林受人为干扰的影响减小，而是由于人为活动的介入和经营管理的限制，人工林分布逐渐趋于集中、连片。次生林和退化林地斑块密度、边缘密度呈现先增加后减小的趋势，但是2009年的斑块密度、边缘密度略高于1990年，说明当地居民对次生林和退化林地的利用在1999年出现了转折，前一时期当地居民不断开发次生林、退化林地转作木薯等旱地和橡胶等人工林，后一时期则放弃旱地，让其自然演化成次生林和退化林地，由于这种开发—利用—弃荒的干扰方式，导致次生林和退化林地在不同时期出现不同程度的破碎化变化。退化原始林、次生林的进一步破碎造成的直接影响是示范区内生物多样性的降低，体现在栖息地的丧失和破碎化。

表 5-5　大敢 FLR 示范区 1990～2009 年景观要素类型斑块密度和边缘密度变化

景观要素类型	斑块密度 PD(个/100hm²)			边缘密度 ED(m/hm²)		
	1990	1999	2009	1990	1999	2009
退化原始林	9.22	11.69	14.27	207.68	278.76	320.19
次生林	84.25	93.87	90.43	494.63	519.56	517.63
退化林地	140.85	214.13	204.31	646.44	764.70	684.69
人工林	76.38	41.11	5.83	485.65	440.44	222.24
旱地	12.88	29.51	195.82	258.97	355.65	671.17
水田	78.30	78.30	78.30	511.79	511.79	511.79
居民点	36.06	36.06	36.06	254.85	254.85	317.70
水库	500.00	500.00	500.00	668.93	668.93	843.99

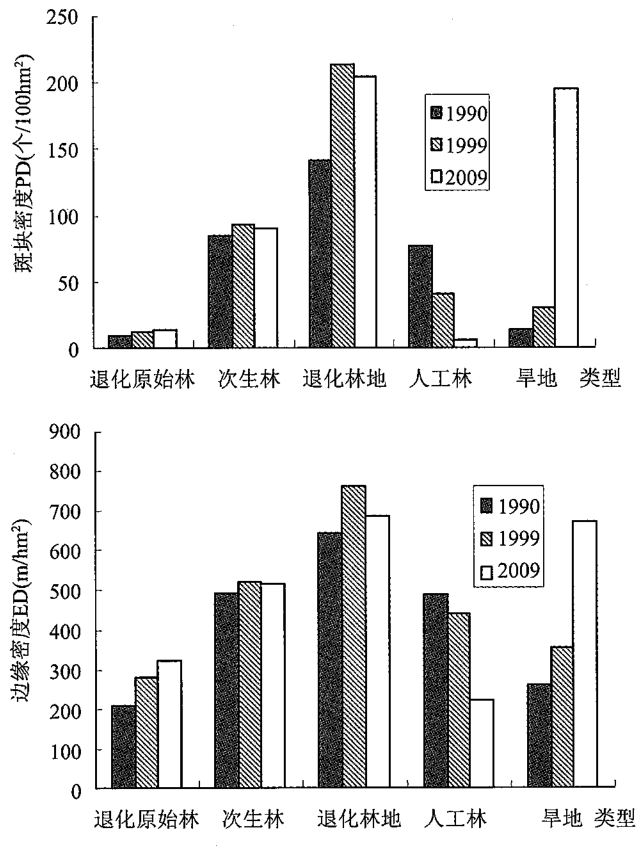

图 5-3　大敢 FLR 示范区 1990～2009 年斑块密度和边缘密度变化

5.4.3 景观总体特征变化

示范区在1991～1999年间和1999～2008年间两个不同时期呈现出不同的变化趋势(见表5-6)。1990年示范区景观以旱地和退化原始林为主，旱地和退化原始林可以看作基质性景观要素类型。1990 ~1999年间，景观斑块数明显增加，从124增加到162，斑块密度、边缘密度、平均斑块形状指数都有明显增加，平均斑块面积减小，从1990年的3.22hm^{2}增加到1999年的2.47hm^2，表明这一时期景观破碎化程度加强，景观各斑块的边界越来越不规则，由斑块数量和形状决定的景观异质性上升。前文分析得出，这一时期退化原始林和次生林大幅减少，而人工林面积迅速增加，因此示范区1999年逐渐演变为以旱地、退化原始林和人工林为主的景观格局，景观优势度下降。这一结论也从多样性指数、均匀度指数和优势度指数的变化上得到反应，多样性指数、均匀度指数分别由1990年的1.45、0.70增加到1999年的1.54和0.74，而均匀度指数也相应从0.63下降为0.54。1999 ~2009年间，示范区斑块从162减到159，斑块密度、边缘密度也略有降低，平均斑块面积从1999年的2.47提高到2009年的2.51，略有增大，表明景观破碎化程度有所缓和，景观异质性有所下降，同时平均斑块形状指数的减小也反映了景观各斑块形状趋向于规则。这一时期的多样性指数、均匀度指数也呈下降趋势，2009年的多样性指数、均匀度指数分别为1.35和0.65，景观优势度指数(0.73)反映出景观存在优势类型。随着1999～2009年间人工林的急剧增加，到2009年示范区的旱地仅分布在人工林之间，已不能再看作示范区的主要景观要素类型，同时退化原始林也仅在当地居民难以到达或立地条件较差的山顶区域，此时示范区景观以人工林为主。

表5-6 大敢FLR示范区1991～2009年景观格局总体特征变化

时间(年)	面积(hm^2)	斑块数NP(n)	斑块密度PD(个/100hm^2)	平均斑块面积MPS(hm^2)	边缘密度ED(m/hm^2)	平均斑块形状指数MSI	多样性指数SDI	均匀度指数SEI	优势度指数D
1990	399.48	124	31.04	3.22	309.73	1.74	1.45	0.70	0.63
1999	399.48	162	40.55	2.47	388.47	1.85	1.54	0.74	0.54
2009	399.48	159	39.80	2.51	329.12	1.63	1.35	0.65	0.73

总的来看，示范区景观由1990年旱地和退化原始林为基质、其他类型镶嵌于其中的格局发展为1999年以旱地、退化原始林、人工林为主体、斑块镶嵌较高、异质斑块交错配置的高度异质景观，最后演变为

2009 年人工林占绝对优势，其他景观要素类型镶嵌其中的景观格局（详见附录 6）。

5.5　大敢村森林景观动态预测

采用 1999 ~ 2009 年的转移概率矩阵模型（见表 5-7），对示范区景观格局动态进行预测（见表 5-8 和图 5-4）。结果表明，若示范区继续保持 1999 ~2009 年的发展趋势，水田、居民点和水库保持稳定，退化原始林面积大幅度减少，从 2009 年的 42.06hm^{2}减少至 2089 年的 3.64 hm^2，占有率（面积比例）下降 9.62%；次生林和退化林地略有增加，人工林缓慢增加，旱地则略有减少，景观异质性降低，到 2089 年前后达到相对稳定状态。各景观要素类型达到稳定状态的占有率分别为：退化原始林 0.91%、次生林 16.75%、退化林地 5.15%、人工林 65.98%、旱地 2.84%。达到稳定状态时，景观格局将由人工林为基质、其他景观要素类型镶嵌分布的结构组成，景观总体结构与目前相比不会发生根本性改变，但是景观质量和生产潜力都将明显下降。其中，由于经济利益的驱

表 5-7　大敢 FLR 示范区 1999 ~ 2009 年景观要素转移概率矩阵①

1999 ~ 2009		DPF	SF	DFL	PL	NPC	PF	HS	RP	1990 年面积
DPF	面积(hm^2)	42.06	11.26	2.84	12.19	0.07	-	-	-	68.42
	(%)	61.47	16.46	4.15	17.82	0.1	-	-	-	100
SF	面积(hm^2)	-	19.01	1.82	8.13	0.87	-	-	-	29.83
	(%)	-	63.73	6.1	27.25	2.92	-	-	-	100
DFL	面积(hm^2)	-	0.76	1.33	1.86	0.72	-	-	-	4.67
	(%)	-	16.27	28.48	39.83	15.42	-	-	-	100
PL	面积(hm^2)	-	6.53	3.33	75.9	1.81	-	-	-	87.57
	(%)	-	7.46	3.8	86.67	2.07	-	-	-	100
NPC	面积(hm^2)	-	9.99	8.79	142.22	11.85	-	-	-	172.84
	(%)	-	5.78	5.09	82.28	6.86	-	-	-	100
PF	面积(hm^2)	-	-	-	-	-	26.82	-	-	26.82
	(%)	-	-	-	-	-	100	-	-	100
HS	面积(hm^2)	-	-	-	-	-	-	8.32	-	8.32
	(%)	-	-	-	-	-	-	100	-	100
RP	面积(hm^2)	-	-	-	-	-	-		1	1
	(%)	-	-	-	-	-	-		100	100
1999 年面积		42.06	47.55	18.11	240.3	15.32	26.82	8.32	1	399.48

①：DPF—退化原始林，SF—次生林，DFL—退化林地，PL—人工林，NPC—解放军地，PF—水田，HS—居民点。

表 5-8 大敢 FLR 示范区景观格局现状与预测

时间(年)	各分期占有率(%)							
	退化原始林	次生林	退化林地	人工林	旱地	水田	居民点	水库
2009	10.53	11.90	4.53	60.15	3.84	6.71	2.08	0.25
2019	6.47	14.77	4.94	62.22	2.57	6.71	2.08	0.25
2029	3.98	16.07	5.07	63.18	2.66	6.71	2.08	0.25
2039	2.45	16.59	5.13	64.05	2.75	6.71	2.08	0.25
2049	1.50	16.70	5.15	64.77	2.79	6.71	2.08	0.25
2059	1.30	16.74	5.15	65.32	2.82	6.71	2.08	0.25
2069	1.10	16.75	5.15	65.71	2.83	6.71	2.08	0.25
2079	1.92	16.75	5.15	65.91	2.84	6.71	2.08	0.25
2089	0.91	16.75	5.15	65.98	2.84	6.71	2.08	0.25

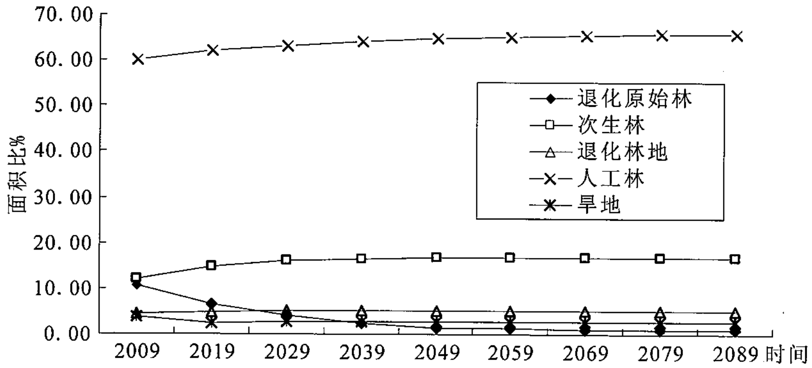

图 5-4 大敢 FLR 示范区景观格局现状与预测

动和刀耕火种等传统耕作方式引起的人为干扰，退化原始林将不断被开发、转成人工林，而示范区的退化原始林主要分布在海拔较高的山顶区域，具有极其重要的生态安全功能，是示范区生态环境建设的主体，这类森林的消失将直接引起示范区生物多样性丧失、水土流失等环境问题，进而引起林产品质量下降、能源缺乏、居民收入降低等社会经济问题。这种发展趋势与示范区天然林保护和社会经济发展规划不符，因此必须对目前的景观格局进行适当干预，保护退化原始林，合理发展人工林，促使土地利用向良性方向转移。

5.6 小 结

本章以大敢 FLR 示范区为案例，从景观要素分类、数据获取与处理、景观格局与动态分析等方面，研究了社区水平景观格局分析技术。

(1)社区水平景观格局分析基础数据的获取依靠遥感信息提取和参

与式小班区划与小班调查相结合的方法，大敢 FLR 示范区景观总面积 399. 48hm^2，呈现以人工林景观为主体、其他景观要素类型镶嵌分布的格局。其中人工林占景观总面积的 60. 15%。次生林、退化原始林分别占总面积的 11. 90% 和 10. 53%，位于南部海拔较高、人为活动较少的山顶，退化林地和旱地则镶嵌于人工林、退化原始林和次生林之间，示范区大小水库(水塘)有 5 处，水田沿河溪两岸、水库周边分布，居民点则位于周山包围的盆地中，水田、居民点的分布相对集中。景观破碎化严重，尤其是退化原始林、次生林和退化林地斑块，景观异质性相对较低。

(3)1990 ~2009 年间示范区景观由 1990 年旱地和退化原始林为基质、其他类型镶嵌于其中的格局发展为 1999 年以旱地、退化原始林、人工林为主体、斑块镶嵌较高、异质斑块交错配置的高度异质景观，最后演变为 2009 年人工林占绝对优势，其他景观要素类型镶嵌其中的景观格局，主要体现在旱地、退化原始林的减少和人工林的增加上，其中退化原始林损失、人工林扩张主要发生在 1990 ~1999 年间，而旱地减少、人工林增加主要出现在 1999 ~2009 年期间。

(4)景观动态预测结果表明：退化原始林面积大幅度减少，次生林和退化林地略有增加，人工林缓慢增加，旱地则略有减少，景观异质性降低，到 2089 年前后达到相对稳定状态。各景观要素类型达到稳定状态的占有率分别为：退化原始林 0. 91%、次生林 16. 75%、退化林地 5. 15%、人工林 65. 98%、旱地 2. 84%。达到稳定状态时，景观格局将由人工林为基质、其他景观要素类型镶嵌分布的结构组成，景观总体结构与目前相比不会发生根本性改变，但是景观质量和生产潜力都将明显下降，这种发展趋势与示范区天然林保护和社会经济发展要求不符，因此必须对目前的景观格局进行适当干预，保护退化原始林，合理发展人工林，促使土地利用向良性方向发展。

第六章　森林景观变化驱动力分析

森林景观恢复是对森林景观整体结构与功能的恢复，而我们所经营和恢复的森林景观又是动态因素的产物，因此在实施森林景观恢复前，不仅要理解森林景观动态，还必须分析出森林景观变化的动因，为有针对性提出恢复策略提供科学依据。

森林景观的变化是人类活动作用于自然资源与环境的一种最为显著的表现形式，其发生和发展一方面受到区域自然地理环境背景的直接控制，主要包括气候、地貌、土壤等以及原生林地覆盖类型，另一方面也受到人类活动的干扰，主要表现为人类影响的可达性与频率以及对林地利用方式的选择，包括人口分布、交通状况、社会需求以及经济产业结构等(李克让等，2000；温庆忠，2002；徐新良等，2004a；李月辉等，2006；匡文慧等，2006)。

国内学者近年来对森林景观变化和驱动力进行了大量的实例分析(卢玲等，2001；张永民等，2004；李景刚等，2004；刘纪远等，2009)。对景观变化多采用面积统计对比、转移矩阵分析或景观指数变化进行分析(马荣华等，2001；刘纪远等，2002；宋冬梅，2003；陈文波，2004；刘淼，2005)。对景观变化驱动力多采用定性分析(陈文波，2004；徐新良等，2004b)，以及主成分分析、多元统计等定量分析方法(曹宇，2004；刘旭华，2005)和 Logistic 回归模型空间分析方法(刘淼等，2007；谢花林，2008)，这些研究方法能较好地反映景观的数量变化、空间变化和空间驱动力。本章分别以陵水黎族自治县和大敢 FLR 示范区为例，采用转移概率矩阵和参与式调查相结合的方法，研究区域水平和社区水平 FLR 中景观动态变化的驱动力分析技术。

6.1　区域水平驱动力分析

6.1.1　转移概率与面积矩阵分析

分析景观格局变化趋势时，常用的研究方法是建立转移概率矩阵，该方法的思想是基于生态学研究中的 Markov 模型，本研究在应用 Markov 模型预测景观格局动态的同时，也试图应用转移概率矩阵来定量分析不同景观要素类型之间的转变与转化，即每一景观要素类型的增加量

或减少量是从哪一种类型变化而来的，或它又变化为哪一种景观要素类型，以及变化的量是多少。因此，沿用前文的景观要素分类系统，确定系统的状态为 13 类景观要素类型，在 GIS 支持下，通过各时期(1991、1999 和 2008 年)景观要素图层之间的叠加操作，确定不同时期各斑块保持不变的面积和转化为其他类型的斑块面积，计算各景观要素类型之间的转换面积占该类型原有面积的比率作为转移概率，以矩阵形式表示，构成相应期间各类景观要素之间的转移概率矩阵。详见表 6-1、表 6-3 和表 4-9。

6.1.1.1　1991 ~ 1999 年各景观要素间转移概率

表 6-1　陵水黎族自治县 1991 ~ 1999 年景观要素转移概率矩阵[①]

1991	1999												
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL
PF	100	-	-	-	-	-	-	-	-	-	-	-	-
DPF	-	82.20	15.00	2.01	-	0.01	-	0.05	-	0.05	-	0.26	0.41
SF	-	-	77.36	3.07	8.94	1.22	-	0.95	0.15	0.38	0.90	5.58	1.43
DFL	-	-	-	19.82	2.87	1.52	-	53.39	0.00	1.35	0.08	18.06	2.90
RP	-	-	-	2.28	69.62	1.22	-	6.56	1.99	0.64	0.92	14.37	2.40
TaV	-	-	-	0.06	0.45	49.44	-	4.57	0.15	10.00	1.86	31.87	1.60
CeP	-	-	-	0.32	-	14.17	13.44	14.32	0.23	2.22	0.65	36.31	18.34
OP	-	-	-	0.64	1.91	22.34	0.07	18.20	5.49	2.42	12.81	31.80	4.32
OFL	-	-	-	0.38	0.61	36.33	-	11.30	1.36	6.77	1.17	41.10	0.97
RQL	-	-	-	0.31	2.52	17.66	0.12	2.36	0.23	67.67	0.62	7.38	1.12
GP	-	-	-	-	1.05	26.43	-	8.07	2.95	2.64	11.92	41.29	5.66
AL	-	-	-	0.36	1.57	9.01	0.12	3.13	1.74	2.17	1.46	76.47	3.97
OL	-	-	-	1.29	0.50	3.04	2.66	4.25	1.48	1.07	0.19	18.20	67.32

①：PF - 原始林，DPF - 退化原始林，SF - 次生林，DFL - 退化林地，RP - 橡胶林，TaV - 村旁树，CeP - 木麻黄人工林，OP - 其他人工林，OFL - 其他林地，RQL - 居住用地，GP - 园地，AL - 农用地，OL - 其他用地。

由表 6-1 和表 6-2 得知，1991 ~ 1999 年间，除原始林没有发生面积转移外，其他景观要素类型之间转移活跃。退化原始林面积的 82.20% 保持不变，15.00% 转化为次生林，另有 2.01% 和 0.41% 分别转化为退化林地和其他用地，而没有其他景观要素类型向退化原始林转化，造成 1999 年退化原始林的面积小于 1991 年；次生林面积的 77.36% 保持稳定，其他 12.64% 主要转化为橡胶林、农用地、退化林地和其他人工林等类型，占 1991 年景观总面积的 7.09%，大于退化原始林向次生林转化的面积(占 1991 年景观总面积的 1.36%)，因此次生林的面积呈现下降趋势。退化林地的转移比较活跃，主要是开发为人工林和农用地。橡

胶林面积增加是因为次生林被开发为橡胶林的面积大于橡胶林向农地和人工林的转移面积；木麻黄人工林面积急剧减少的原因是这一时期沿海防护林因虾塘、采矿而遭到破坏，36.31%的面积转移为农用地；转移面积占景观总面积的0.62%。园地和农用地面积略有增加，但是斑块转移比较活跃。

表6-2 陵水黎族自治县1991～1999年景观要素面积转移矩阵①

1991	1999													1991
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL	
PF	4.74	-	-	-	-	-	-	-	-	-	-	-	-	4.74
DPF	-	7.48	1.36	0.18	-	-	-	-	-	-	-	0.02	0.04	9.10
SF	-	-	24.22	0.96	2.80	0.38	-	0.30	0.05	0.12	0.28	1.75	0.45	31.31
DFL	-	-	-	0.17	0.03	0.01	-	0.47	-	0.01	0.00	0.16	0.03	0.88
RP	-	-	-	0.17	5.26	0.09	-	0.50	0.15	0.05	0.07	1.08	0.18	7.55
TaV	-	-	-	-	0.01	1.04	-	0.10	0.00	0.21	0.04	0.67	0.03	2.10
CeP	-	-	-	0.01	-	0.24	0.23	0.24	0.00	0.04	0.01	0.62	0.31	1.70
OP	-	-	-	0.03	0.10	1.13	-	0.92	0.28	0.12	0.65	1.61	0.22	5.07
OFL	-	-	-	0.00	-	0.25	-	0.08	0.01	0.05	0.01	0.28	0.01	0.68
RQL	-	-	-	0.01	0.06	0.40	-	0.05	0.01	1.52	0.01	0.17	0.03	2.25
GP	-	-	-	-	0.02	0.38	-	0.12	0.04	0.04	0.17	0.59	0.08	1.43
AL	-	-	-	0.10	0.43	2.46	0.03	0.85	0.47	0.59	0.40	20.85	1.08	27.27
OL	-	-	-	0.08	0.03	0.18	0.16	0.25	0.09	0.06	0.01	1.08	3.99	5.93
1999	4.74	7.48	25.59	1.71	8.72	6.56	0.43	3.88	1.10	2.81	1.66	28.88	6.44	100

②：PF-原始林，DPF-退化原始林，SF-次生林，DFL-退化林地，RP-橡胶林，TaV-村旁树，CeP-木麻黄人工林，OP-其他人工林，OFL-其他林地，RQL-居住用地，GP-园地，AL-农用地，OL-其他用地。表中各项为转移面积占景观总面积的比例。

总的来看，这一时期各景观要素类型的变化模式呈现为：退化原始林被开发利用为次生林，而次生林又被开发为橡胶林、农用地和退化林地，退化林地则得到人工造林或开发为农用地，农用地逐渐发展为村旁树、其他人工林和其他用地。其中退化林地和农用地可以看作这一时期的过渡类型。

6.1.1.2 1999～2008年各景观要素间转移概率

分析表4-9和表6-3得出，1999～2008年间，原始林保持稳定，没有发生任何转移。部分退化原始林被开发为次生林、园地，分别占原有退化原始林面积的11.39%、2.79%，另有1.24%的面积转为退化林地，

表 6-3　陵水黎族自治县 1999 ~ 2008 年景观要素面积转移矩阵①

1999	2008													1999
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL	
PF	4.74	-	-	-	-	-	-	-	-	-	-	-	-	4.74
DPF	-	6.29	0.85	0.09	-	-	-	-	-	-	0.21	-	0.03	7.48
SF	-	-	21.95	0.93	0.31	0.18	-	0.90	-	0.04	0.66	0.50	0.11	25.59
DFL	-	-	-	0.16	0.23	0.03	0.01	0.97	-	0.01	0.17	0.08	0.04	1.71
RP	-	-	-	0.42	5.50	0.21	-	0.65	0.04	0.07	1.11	0.61	0.11	8.72
TaV	-	-	-	0.02	0.04	2.60	0.02	0.45	0.01	0.72	0.71	1.75	0.23	6.56
CeP	-	-	-	-	-	0.01	0.05	-	-	0.02	-	0.23	0.12	0.43
OP	-	-	-	0.12	0.32	0.48	0.06	0.92	0.04	0.14	0.62	0.89	0.29	3.88
OFL	-	-	-	-	0.07	0.05	-	0.08	0.02	0.03	0.28	0.56	0.01	1.10
RQL	-	-	-	0.03	0.07	0.54	0.01	0.09	-	1.75	0.09	0.20	0.04	2.81
GP	-	-	-	0.00	0.14	0.15	-	0.10	-	0.03	0.50	0.72	0.02	1.66
AL	-	-	-	0.32	0.81	2.32	0.08	1.91	0.05	0.86	3.22	17.83	1.47	28.88
OL	-	-	-	0.07	0.17	0.20	0.20	0.59	0.01	0.12	0.43	1.16	3.49	6.44
2008	4.74	6.29	22.80	2.17	7.66	6.78	0.42	6.66	0.16	3.80	8.00	24.54	5.96	100

①：PF - 原始林，DPF - 退化原始林，SF - 次生林，DFL - 退化林地，RP - 橡胶林，TaV - 村旁树，CeP - 木麻黄人工林，OP - 其他人工林，OFL - 其他林地，RQL - 居住用地，GP - 园地，AL - 农用地，OL - 其他用地。表中各项为转移面积占景观总面积的比例。

转移面积占景观总面积的 1. 19%；并且没有其他类型向退化原始林转移，造成退化原始林面积减少。85. 78% 的次生林未发生转移，其他转为退化林地、其他人工林、园地和农用地等，并且转移的面积(3. 64%)大于由退化原始林向次生林转移的面积(0. 85%)，导致次生林面积减少；橡胶林在这一时期面积减少，其中有 12. 73% 向园地转移，转移面积比例为 1. 11%，主要原因是已过收获期的橡胶林逐渐向园地、农用地过渡。园地与其他景观要素类型的转移较为活跃，1999 年园地面积的 30. 10% 在 2008 年未发生转移，即保持景观总面积的 0. 50% 稳定，其他面积主要转为农用地、村旁树和橡胶林等类型，转移面积分别为 1999 年园地面积的 43. 69%、9. 26%、8. 16%，同时其他林地、其他人工林、橡胶林、农用地等也有部分斑块向园地转移，转移程度各异，并且其他类型向园地的转移面积大于园地转为其他类型的面积，形成 1991 ~ 2008 年间园地面积急剧增加的变化。农用地面积有所下降，除转为园地外，也部分转为村旁树、其他人工林和其他用地等类型。

6.1.1.3 1991～2008 年各景观要素间转移概率

1991～2008 年间，陵水黎族自治县原始林保持稳定，其他景观要素类型之间均发生不同程度的转移(见表 6-4 和表 6-5)。退化原始林保持其面积的 69.18% 稳定，其他 30.82% 向次生林、园地、其他人工林、和退化林地转移，其中转为次生林的面积占退化原始林面积的 23.88%，即景观总面积的 2.17%，但是由于退化原始林自身的林分特点，这一时期并没有其他类型向其转化，造成 1991～2008 年的 17 年间退化原始林面积减少。次生林的变化比较活跃，1991 年次生林面积的 34.11% 在 2008 年转移为其他人工林(9.31%)、橡胶林(7.74%)、园地(5.18%)、农用地(4.37%)和退化林地(4.24%)等，并且转移面积大于退化原始林向次生林的转移，导致次生林面积持续减少。退化林地的变化非常活跃，1991～2008 年间，只有其面积的 11.47% 未发生转移，其他 88.53% 分别向其他人工林(51.54%)、其他用地(10.61%)、村旁树(7.64%)、农用地(7.58%)和园地(5.75%)等类型转移。橡胶林在这一时期面积略有增加，原因是橡胶林向园地和农用地等类型的转移面积小于次生林、农用地和人工林等其他类型转移为橡胶林的面积。村旁树在这一时期

表 6-4 陵水黎族自治县 1991～2008 年景观要素转移概率矩阵①

1991	2008												
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL
PF	100.00	-	-	-	-	-	-	-	-	-	-	-	-
DPF	-	69.18	23.88	1.32	0.15	-	-	2.05	-	0.01	2.91	0.07	0.43
SF	-	-	65.89	4.24	7.74	1.62	0.01	9.31	0.10	0.58	5.18	4.37	0.95
DFL	-	-	-	11.47	1.31	7.64	0.01	51.54	-	4.09	5.75	7.58	10.61
RP	-	-	-	3.33	57.02	3.22	-	5.93	0.68	0.79	17.83	9.99	1.22
TaV	-	-	-	-	-	52.53	-	4.15	-	14.62	3.61	23.74	1.34
CeP	-	-	-	-	-	10.92	5.50	2.10	0.24	6.89	4.06	46.42	23.87
OP	-	-	-	0.29	5.17	19.92	0.12	8.20	0.10	3.75	19.44	38.37	4.65
OFL	-	-	-	0.86	3.16	20.46	0.15	5.95	0.02	14.07	14.52	35.25	5.56
RQL	-	-	-	0.84	3.41	20.45	0.16	1.71	-	63.44	2.49	6.64	0.87
GP	-	-	-	0.09	0.58	20.51	0.30	5.92	-	5.02	21.94	41.89	3.74
AL	-	-	-	0.93	1.83	9.40	0.11	5.74	0.17	4.37	10.68	61.72	5.06
OL	-	-	-	1.32	0.71	3.52	4.61	6.62	0.40	2.05	3.55	21.85	55.36

①：PF－原始林，DPF－退化原始林，SF－次生林，DFL－退化林地，RP－橡胶林，TaV－村旁树，CeP－木麻黄人工林，OP－其他人工林，OFL－其他林地，RQL－居住用地，GP－园地，AL－农用地，OL－其他用地。

表 6-5　陵水黎族自治县 1991～2008 年景观要素面积转移矩阵①

1991	2008													1991
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL	
PF	4.74	-	-	-	-	-	-	-	-	-	-	-	-	4.74
DPF	-	6.29	2.17	0.12	0.01	-	-	0.19	-	-	0.26	0.01	0.04	9.10
SF	-	-	20.63	1.33	2.42	0.51	-	2.92	0.03	0.18	1.62	1.37	0.30	31.31
DFL	-	-	-	0.10	0.01	0.07	-	0.45	-	0.04	0.05	0.07	0.09	0.88
RP	-	-	-	0.25	4.30	0.24	-	0.45	0.05	0.06	1.35	0.75	0.09	7.55
TaV	-	-	-	-	-	1.10	-	0.09	-	0.31	0.08	0.50	0.03	2.10
CeP	-	-	-	-	-	0.19	0.09	0.04	-	0.12	0.07	0.79	0.41	1.70
OP	-	-	-	0.01	0.26	1.01	0.01	0.42	-	0.19	0.99	1.94	0.24	5.07
OFL	-	-	-	0.01	0.02	0.14	-	0.04	-	0.10	0.10	0.24	0.04	0.68
RQL	-	-	-	0.02	0.08	0.46	-	0.04	-	1.43	0.06	0.15	0.02	2.25
GP	-	-	-	-	0.01	0.29	-	0.08	-	0.07	0.31	0.60	0.05	1.43
AL	-	-	-	0.25	0.50	2.56	0.03	1.56	0.05	1.19	2.91	16.83	1.38	27.27
OL	-	-	-	0.08	0.04	0.21	0.27	0.39	0.02	0.12	0.21	1.30	3.28	5.93
2008	4.74	6.29	22.80	2.17	7.66	6.78	0.42	6.66	0.16	3.80	8.00	24.54	5.96	100

①：PF－原始林，DPF－退化原始林，SF－次生林，DFL－退化林地，RP－橡胶林，TaV－村旁树，CeP－木麻黄人工林，OP－其他人工林，OFL－其他林地，RQL－居住用地，GP－园地，AL－农用地，OL－其他用地。表中各项为转移面积占景观总面积的比例。

主要转为农用地、居住用地，但是转移面积远小于其他类型向村旁树的转移。木麻黄人工林面积显著降低，在维持部分面积稳定的同时，其余 89.08% 转为农用地、其他用地、居住用地等类型。农用地面积有所减少，主要发生在农用地向园地（10.68%）、村旁树（9.40%）、其他人工林（5.74%）和其他用地（5.06%）的转移上。

分析以上三期转移概率矩阵可以发现以下规律：由原始林、退化原始林和次生林构成的天然林面积持续减少的原因是天然林向人工林、农地、园地和居住用地转移，而这种转移具有不可逆性。原始林是所有景观要素类型中最稳定的，而其他景观要素类型之间的转移存在一定差异；退化原始林和次生林的面积都呈现下降的趋势，原因是部分退化原始林向次生林演化，次生林向其他人工林、橡胶林、园地和农用地转移，其中向橡胶林和农用地的转移主要发生在 1991～1999 年期间，向退化林地、其他人工林、园地的转移主要发生在 1999～2008 年间，这也是造成橡胶林、农用地在 1991～1999 年面积增加的主要原因。

6.1.2 驱动力分析

森林景观变化的驱动力一般分为自然因子和人为因子两类，自然驱动力主要指在景观发育过程中对景观形成和发展起作用的自然因子，主要包括地质地貌的形成、气候的影响、动植物的定居、土壤的发育和自然干扰等；而人为驱动力的类型、方向、大小等都更加复杂(郭晋平和周志翔，景观生态学，2007)，包括人口、技术、政治经济体制、政策和文化等因子(徐新良等，2004a)。自然因子和人为因子的作用方式不同，森林景观的响应也不同，需要采取不同的方法分别加以研究。

通过分析转移概率矩阵，可以得出每一景观要素类型的增减来源，如退化原始林面积的减少主要是因为只有这一类型部分面积向次生林和退化林地转移，而由退化原始林向次生林转移的面积远低于次生林向橡胶林、农用地、退化林地等的转移，是造成次生林面积持续减少的原因，但是驱动这种转移的因素却不能由转移概率矩阵得出。为此，本研究在分析转移概率矩阵的基础上，采用多种公众参与的方法(如半结构访谈、矩阵排序、问题因果分析、头脑风暴等)，与陵水黎族自治县林业局、农业局、国土环境资源局、水务局、扶贫办、海洋与渔业局、旅游局、发展和改革局等与土地利用相关的政府部门，以及省属国营南平农场、岭门农场和罗吊山林业局三个国有机构等主要利益相关者代表不断交流、讨论，结合不同地区的居民访谈、实地考察和相关文献资料，对陵水黎族自治县 1991 ~2008 年森林景观格局变化的驱动力进行分析。

6.1.2.1 林业政策与重点工程是森林数量与质量提高的主导因素

1993 年 7 月 30 日海南省第一届人民代表大会常务委员会第三次会议通过《海南省森林保护管理条例》，自 1994 年 1 月 1 日起禁止采伐全省范围内的热带天然林；1998 年启动天然林资源保护工程；1999 年 7 月 30 日海南省第二届人民代表大会常务委员会第八次会议通过《海南生态省建设规划纲要》；2002 年开始实施退耕还林工程；实施的林业重点工程还有野生动植物保护及自然保护区建设工程、重点生态公益林保护工程、沿海防护林保护与建设工程和速生丰产用材林基地建设工程。这些林业重点工程的实施，不仅有效遏制了之前热带天然林不断减少的态势，有效保护和恢复了热带天然林(特别是北部吊罗山国有林区)，同时增加了热带人工林的面积，提高了热带天然林的林分质量，1994 年的二类调查和 2005 年的二类抽样调查结果表

明，天然林的单位面积蓄积量从 175.5 m^3/hm^2 增加到 207.5 m^3/hm^2，增加 18.2%。

6.1.2.2　扶贫开发是西部丘陵地区和北部浅山地区森林景观变化的主要因素

扶贫开发作为近年来陵水黎族自治县西部丘陵地区和北部浅山地区的最大工程，现已形成驱动该区森林景观格局变化的主要因素。为完成《中国农村扶贫开发纲要(2001～2010 年)》提出的目标和任务，按海南省扶贫办《2006 年贫困地区干部培训规划》的"县为单位、整合资金、整村推进、连片开发"扶贫开发试点要求，陵水黎族自治县开展了以产业化扶贫为突破口的种植基地建设，现已开发群英乡、本号镇祖关村等橡胶基地 15 个，种植橡胶 1333hm^2，开辟槟榔基地 10 个，扶持种植槟榔 533hm^2，扶持种植和管理杧果 1300hm^2。2008 年陵水又投入 80 万元在本号镇、隆广镇等乡镇种植槟榔 167hm^2，扶持种苗 28 万株；投入 50 万元在本号镇、隆广镇和群英乡等乡镇种植橡胶 15hm^2，扶持种苗 12 万株；根据农户管理要求，投入 60 万元扶持贫困户管理橡胶 200hm^2，槟榔 133hm^2，杧果 200hm^2。

尽管这种充分利用贫困地区资源优势的坚持开发式、"整村推进"和"三集中"的扶贫工作方针增强了农村经济发展的后劲，如已扶持 46 个贫困行政村和文明生态村 1418 户种植槟榔，2195 户 98775 人种植杧果，但由于种植基地的形成必须依靠大量土地利用方式的转换，造成种植区的退化原始林、次生林、退化林地、其他人工林和农用地等类型转移为园地类型。

6.1.2.3　生计开发是整个丘陵地区和浅山地区森林景观变化的重要因素

陵水黎族自治县为国家级贫困县，经济发展相对落后，居民生活相对贫困，在整个丘陵地区和浅山地区农地相对较少，为生计的需要开发山地发展经济作物成为重要选择，加上黎族的传统耕作方式——"刀耕火种"(游耕农业)，以家庭为单位、小规模的、"刀耕火种"式的山地开发构成这个地区森林景观变化的主要因素，造成退化原始林和次生林的严重蚕食。

6.1.2.4　村旁绿化和农田防护林网是中部平原农区森林景观变化的重要因素

新农村建设、生态文明村建设是村旁树不断增加的原因。对农田防风和保护的需要，是平原农区无意中农田防护林网形成的因素。村

旁树和农田防护林网不断发展，已成为中部平原农区重要的生态安全屏障。

6.1.2.5　采砂、池塘养殖和旅游开发是沿海地区森林景观变化的主要因素

20 世纪 90 年代初期陵水黎族自治县沿海防护林面积大、木麻黄长势非常好，1991～1994 年间由于开采钛矿，沿海防护林受到严重破坏，面积急剧减少，1995～1998 年间由于全省“消灭荒山”，沿海防护林得到恢复；但 2004 年前后又出现高收入的池塘养殖产业和西瓜产业，经济利益驱动下沿海防护林被转移为虾塘或瓜田，沿海防护林再度遭受严重破坏。2007 年 11 月 29 海南省第三届人民代表大会常务委员会第三十四次会议通过《海南省沿海防护林建设与保护规定》；沿海防护林恢复已提到建设“三个陵水”目标的高度，特别是生态县的高度，根据陵府[2007]9 号加强沿海防护林保护的通知，从高潮线起 200 米的沿海特殊防护林带，任何单位和个人不得征、占用林地，对省级以上重点项目须征、占用的必需留足至少 100 米宽的防护林带，并依法办理有关林地使用手续；已实施“退塘还林”等工程恢复沿海防护林，林下套种西瓜也被严格控制在不影响防护林正常生长的范围内。近年来的旅游开发一定程度上又影响到沿海防护林的发展。

6.2　社区水平驱动力分析

6.2.1　转移概率与面积矩阵分析

6.2.1.1　1990～1999 年各景观要素间转移概率

1990～1999 年间，退化原始林斑块有 29.97% 的面积发生转换，且主要转换为旱地和次生林，转换面积分别为 14.20 hm^2 和 12.90 hm^2，约占原有退化原始林面积的 14.54% 和 13.21%（表 6-6），但是没有其他类型向退化原始林转移，导致退化原始林面积减少。次生林地主要被开发为旱地（12.73 hm^2）和转移为人工林（5.22 hm^2），分别占次生林面积的 36.98% 和 15.71%，并且这种开发和转移的面积大于退化林地等类型向次生林的演化面积。退化林地也主要转换为旱地和人工林，分别占退化林地面积的 35.21% 和 29.58%。人工林因技术、管理和投入等限制而收益较差，部分人工林又被开发为旱地，面积为 5.71 hm^2，占人工林地面积的 16.17%，但是退化原始林、次生林、退化林地和旱地向人工林的转移面积远大于人工林向旱地的转移，导致这一时期人工林面积急剧增加。

表 6-6 大敢 FLR 示范区 1990～1999 年景观要素转移概率矩阵①

1990～1999		DPF	SF	DFL	PL	NPC	PF	HS	RP	1990 年面积
DPF	面积(hm^2)	68.42	12.9	0.36	1.76	14.2	-	-	-	97.64
	(%)	70.07	13.21	0.37	1.8	14.54	-	-	-	100
SF	面积(hm^2)	-	15.8	0.67	5.22	12.73	-	-	-	34.42
	(%)	-	45.9	1.95	15.17	36.98	-	-	-	100
DFL	面积(hm^2)	-	-	2	1.68	2	-	-	-	5.68
	(%)	-	-	35.21	29.58	35.21	-	-	-	100
PL	面积(hm^2)	-	0.38	-	25.33	5.71	-	-	-	31.42
	(%)	-	1.21	0	80.62	18.17	-	-	-	100
NPC	面积(hm^2)	-	0.75	1.64	53.58	138.2	-	-	-	194.17
	(%)	-	0.39	0.84	27.59	71.17	-	-	-	100
PF	面积(hm^2)	-	-	-	-	-	26.82	-	-	26.82
	(%)	-	-	-	-	-	100	-	-	100
HS	面积(hm^2)	-	-	-	-	-	-	8.32	-	8.32
	(%)	-	-	-	-	-	-	100	-	100
RP	面积(hm^2)	-	-	-	-	-	-	-	1	1
	(%)	-	-	-	-	-	-	-	100	100
1999 年面积		68.42	29.83	4.67	87.57	172.84	26.82	8.32	1	399.48

①：DPF－退化原始林，SF－次生林，DFL－退化林地，PL－人工林，NPCL－解放军地，PF－水田，HS－居民点，RP－水库。

从发生转换的空间分布来看，旱地向人工林的转移主要发生在示范区的中北部尤其北部区域，退化原始林被开发为旱地的斑块主要分布于示范区的南部低山区域，伴随旱地因被用作人工林种植而带来的面积减少，为解决基本的生活需求对土地的依赖，示范区社区居民通常采取的方式即是开发现有退化原始林，退化原始林向次生林的演化主要发生于示范区的东南角和西边低山的退化原始林边缘区，次生林被开发为旱地主要出现在示范区的南部区域，但大多为利用方式二次或多次反复转换。沿着"退化原始林或次生林→农地→荒弃→次生林→农地"的循环转换过程进行演替。

6.2.1.2 1999～2009 年各景观要素间转移概率

1999～2009 年间退化原始林面积减少的原因是 26.36 hm^2 的退化原始林转为人工林、次生林、退化林地和旱地，分别占 1999 年退化

原始林面积的17.82%、16.46%、4.15%和0.1%。次生林相对稳定，部分(8.13 hm^2)用作人工林种植，占1999年次生林面积的27.25%，但是由退化原始林、人工林、旱地转移而来的次生林面积较大，形成这一时期次生林面积显著增加的趋势。退化林地相对活跃，在维持面积的28.48%稳定的同时，直接转换为人工林的面积占退化林地的39.83%，另有部分退化林地因荒弃时间较长而更新为次生林，但也有少部分退化林地被开垦为旱地，同时，旱地、退化原始林、次生林和人工林都部分转为退化林地，导致退化林地面积增加。人工林除少部分荒弃为次生林、退化林地或开垦为旱地外，这一时期主要呈大幅增加趋势。与人工林地面积相反，旱地减少面积达142.22 hm^2，占原有旱地面积的82.28%，大部分都被用作人工林种植橡胶、槟榔、桉树等经济林果，这正是人工林面积急剧增加、旱地面积急剧减少的主要原因。从演化方向来看，旱地向人工林的转移是这一时期的主导方向，且分布广泛。其次，退化原始林被开发为人工林，主要出现在示范区的西南部。与前一时段相比，这一时段的退化原始林向人工林的转换，不再首先经过农作物的种植，而直接开垦为人工林。旱地转为次生林主要发生于示范区的西南部，立地条件较差，距离村庄较远，导致开发后的旱地弃荒、天然更新为次生林。次生林被开发为人工林集中分布于居民点西边与小溪间的圆形区域，但示范区南部也有零星斑块分布。退化原始林退化为次生林出现于离居民点较近的东边低山区。

6.2.2 驱动力分析

与区域水平森林景观格局变化驱动力分析相似，本研究在分析社区水平不同时期各景观要素类型之间转移概率的基础上，通过村民大会、半结构访谈、绘制资源图、矩阵排序、问题因果分析等参与式农村评估(PRA)工具，不断与大敢村居民交流、讨论，以此分析大敢FLR示范区景观格局变化的驱动因子。

6.2.2.1 基本生活保障

大敢FLR示范区景观格局变化的驱动因素首先体现为社区居民为满足基本生活保障需求驱动的农用地的扩张。示范区人均耕地仅0.04hm^2，20世纪90年代初期，示范区大多数居民的温饱问题未得到解决，甚至目前仍有少部分居民每年仍有2~3个月缺粮。为解决温饱问题，当地居民大规模开发退化原始林、次生林为农地等，但当时主要为解决基本的生计问题而种植粮食作物木薯。基本生活保障的

满足驱动主要发生于 1990 ~ 1999 年间，体现为退化原始林、次生林和退化林地直接开垦为农地，用于种植木薯和玉米。但生活必需的能源需求则贯穿整个研究时段，薪柴对示范区森林景观要素的变化也起了很大的驱动作用，居民很少使用电、煤、气等其他替代能源。

6.2.2.2　扶贫支农政策

扶贫支农政策是示范区景观格局变化的主要驱动因素。扶贫支农的主要形式是提供人工林、经济林树苗，造成大量木薯等农用地转换为荔枝、杧果等经济林和橡胶、槟榔等人工林。农户响应扶贫政策的积极性很高，通常将居民点、道路和水源附近区域的农用地用做人工林种植。1990 ~ 1999 年间，为加大少数民族地区的扶贫力度，陵水黎族自治县对示范区所属的群英乡实施了提供荔枝、杧果、椰子等种苗、技术和管理培训等形式的扶贫开发，从而促使这一时期退化与次生森林和旱地向人工林的转换。1999 年之后的扶贫政策则转向依托社区居民现有技术和管理经验、发展橡胶、槟榔等产业，致使 1999 ~ 2009 年期间示范区橡胶、槟榔等人工林面积的增加。随着扶贫力度的加大、农户生活水平的提高以及橡胶、槟榔等经济林果效益的提高，大部分木薯地弃荒后形成的次生林也已经改种槟榔、橡胶等人工林，同时在短期经济利益的驱动下，仍存在现有部分次生林被开发的危险，这也是立地水平森林景观恢复所要考虑的关键折衷，即人工林扩张与次生林保护之间的冲突。

6.2.2.3　林产品价格

林产品价格对示范区景观格局的驱动主要出现在 1999 ~ 2009 年间。尤其是最近 5 年，橡胶、槟榔、桉树的价格稳中有升，居民的基本温饱问题也得以解决，不再仅仅依靠扩大木薯和玉米的种植规模来维持生计，而将原先开发的大面积的农用地转为人工林，橡胶、槟榔和桉树等成为受居民喜爱的树种。林产品价格的驱动作用也表现为这一时期退化原始林、次生林或退化林地的开发不再经过旱地的替代，而直接转为人工林。旱地作为前一时段连接退化原始林、次生林或退化林地与人工林之间的过渡类型，在这一时期并未出现，说明示范区居民对扩大人工林种植的渴望强烈。同时，这也提示我们另外一个强信号，即受价格因素的驱动，示范区农户极有可能为扩大人工林种植而将现有退化原始林、次生林或退化林地转换为人工林。

6.2.2.4　传统习俗

传统习俗是示范区景观格局变化的重要驱动因子。示范区所属大

敢村是黎族村，按照当地习俗每户家庭都要为家中男孩预留一定面积的土地，用以男子成家后维持生计。因此，家中有男丁的农户就会尽量开垦土地，退化原始林、次生林或退化林地也就自然而然地转换为农地或人工林，甚至开荒后弃荒。访谈时，农户提起“当孩子长大后，他们会主动向父母要能够养活自己一家人的土地”，而且当家中男孩成长至15～16岁时，家庭通常把他以后所承担的土地分给他，让他自己经营和管理。示范区另一个传统习俗是只要一片山林被开发过，那么大家就约定成俗默认这块土地永久属于开发者。实地踏勘发现，开发后尚未种植的土地周围有标定地界的茅草搭在树枝上，或用一圈石块围起来，或保留一圈低矮的灌木树种等。这种开发习俗或标定地界的做法，在很大程度上促使了示范区退化与次生森林向农地、人工林的转换。

6.3 小 结

本章首先应用Markov模型的转移概率矩阵定量分析不同景观要素类型之间的转变与转化，即每一景观要素类型的增加量或减少量的来源或去向，再以此为基础采用参与式方法探求景观变化的潜在驱动力。结果表明：采用Markov模型建立的转移概率矩阵能够用于景观动态变化驱动力的初步分析；转移概率矩阵和参与式方法相结合的驱动力分析方法同时适用于区域水平和社区水平的森林景观恢复中景观变化动因分析。

(1)陵水黎族自治县三期转移概率矩阵分析结果表明：由原始林、退化原始林和次生林构成的天然林面积持续减少的原因是天然林向人工林、农地、园地和居住用地转移，而这种转移具有不可逆性。原始林是所有景观要素类型中最稳定的，而其他景观要素类型之间的转移存在一定差异；退化原始林和次生林的面积都呈现下降的趋势，原因是部分退化原始林向次生林演化，次生林向其他人工林、橡胶林、园地和农用地转移，其中向橡胶林和农用地的转移主要发生在1991～1999年期间，向退化林地、其他人工林、园地的转移主要发生在1999～2008年间，这也是造成橡胶林、农用地在1991～1999年面积增加的主要原因。

(2)转移概率矩阵分析结合参与式调查分析得出1991～2008年间陵水黎族自治县景观变化的驱动力：林业政策与重点工程是森林数量与质量提高的主导因素，扶贫开发是西部丘陵地区和北部浅山地区森

林景观变化的主要因素，生计开发是整个丘陵地区和浅山地区森林景观变化的重要因素，村旁绿化和农田防护林网是中部平原农区森林景观变化的重要因素，采砂、池塘养殖和旅游开发是沿海地区森林景观变化的主要因素。

(3)大敢 FLR 示范区转移概率矩阵分析结果表明：1990 ~1999 年间，退化原始林退化原始林面积减少的原因是部分退化原始林斑块向旱地和次生林转换，但是没有其他类型向退化原始林转移；次生林地面积减少的原因是被开发为旱地和转移为人工林的面积大于退化林地等类型向次生林的演化面积；退化原始林、次生林、退化林地和旱地向人工林的转移面积远大于人工林向旱地的转移，导致这一时期人工林面积急剧增加。这一时期是沿着“退化原始林或次生林→农地→荒弃→次生林→农地”的循环转换过程进行演替。1999 ~2009 年间退化原始林面积减少的原因是 26.36 hm^2 的退化原始林转为人工林、次生林、退化林地和旱地，由退化原始林、人工林、旱地转移而来的次生林面积较大，形成这一时期次生林面积显著增加的趋势。从演化方向来看，旱地向人工林的转移是这一时期的主导方向，且分布广泛；退化原始林向人工林的转换，不再首先经过农作物的种植，而直接开垦为人工林。

(4)大敢 FLR 示范区 1990 ~2009 年景观动态变化是在基本生活保障、扶贫支农政策、农林产品价格和传统习俗共同驱动下发生的。基本生活保障的满足驱动主要发生于 1990 ~1999 年间，体现为退化原始林、次生林和退化林地直接开垦为农地，用于种植木薯和玉米。扶贫支农政策和农林产品价格作用致使 1999 ~2009 年间退化原始林和农地向人工林的转移，呈现橡胶、槟榔等人工林面积急剧扩张的变化。

第七章　退化与次生森林特征分析及恢复策略

无论是区域水平还是社区水平的森林景观恢复，其具体恢复措施的实施都应落实到立地水平上。相对于其他恢复途径，森林景观恢复更注重退化与次生森林的恢复与经营（ITTO 和 IUCN，2005）。国际热带木材组织（ITTO）在 2002 年提出的《热带退化与次生森林恢复、经营和重建指南》中详细界定了退化与次生森林的类别，包括退化原始林、次生林和退化林地（ITTO，2002）。相比原始林，退化与次生森林通常位于居民点附近的易接近区域，人们对此类森林的利用远远超过对原始林的利用，因此退化与次生森林对边远地区的贫困居民有着特殊的经济重要性，是森林资源中越来越重要的部分（Banerjee A 1995，Gilmour D A 等，2000；Mcshea W J，2009）。

国内有关热带退化原始林的生物多样性、群落结构和动态（李意德，1997；安树青等，1999；臧润国等，2002；丁易，2007；杨彦承等，2008；许涵等，2009），以及次生林类型、主要特征和经营现状（黄世能等，2000；侯元兆，2003；何波祥等，2008；侯元兆等，2008；王洪峰，2008）等方面已经开展了许多重要研究，但从森林经营角度进行热带退化原始林和次生林的群落学特征和测树学特征的研究较少。本章在充分理解不同森林类别的界定的前提下，以海南省陵水黎族自治县大敢 FLR 示范区退化与次生森林为对象，从森林经营角度探讨其林分特征，并根据林分特征提出具体的立地水平恢复策略，旨在为退化与次生森林的保护、恢复、可持续经营和利用提供基础依据。

7.1　ITTO 对热带森林类别的界定

7.1.1　ITTO 热带森林分类体系

《ITTO 热带退化与次生森林恢复、经营和重建指南》（ITTO，2002）将森林划分为三类：原始林（primary forest）、修正天然林（modified natural forest）和人工林（planted forest）。修正天然林又可分为两类：经营原始林（managed primary forest）和退化与次生森林（degraded and secondary forest）。其中退化与次生森林包括退化原始林（degraded primary forest）、次生林（secondary forest）和退化林地（degraded forest land）（如图 7-1）。

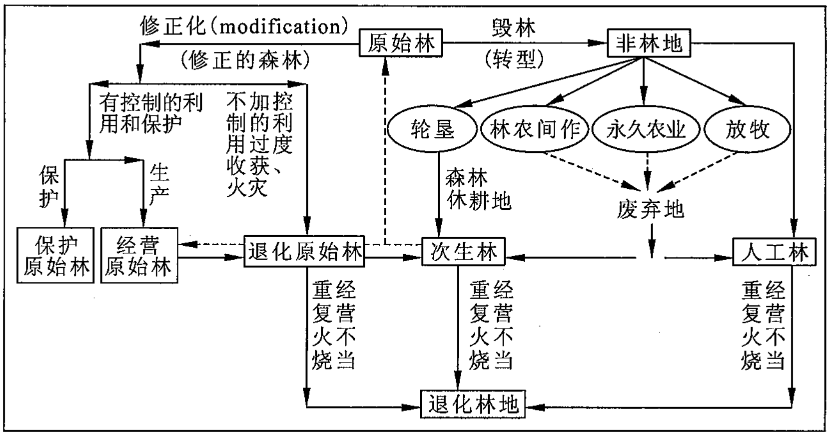

图 7-1　构成不同森林和非森林状态的动态模型

ITTO 划分的不同森林类别之间存在一个动态变化的过程，各类森林相互联系，在一定条件下可以相互转化。森林起源于自然过程，在没有人类大规模干扰以前，可以说所有森林都是原始林，即未受到人类干扰的森林，或受到狩猎、伐木的影响非常小，天然结构、功能和动态过程未发生超过生态系统恢复能力的森林。当原始林是以木质和非木质林产品生产或其他利用为目的而得到有控制的开发利用，则此类原始林为经营原始林；不以生产为目的、受到有效保护的原始林为保护原始林。经营原始林和保护原始林能够提供原始林所具有的主要产品和服务，但是这种利用与保护已经改变了原始林最初的森林结构和物种组成，因此它们属于修正天然林的范畴。如果原始林或经营原始林受到不加控制的过度开发与利用，或受到火灾、风雪等破坏性干扰，其森林结构、功能和动态变化就会超出森林自身的短期恢复能力，即此种状态下的原始林已经发生退化，ITTO 则将此类森林界定为退化原始林。退化原始林仍保留了早先原始林的许多特征，如树种组成、土壤结构、林分结构等，通过去除森林退化的干扰因素，依靠天然更新和自然演替过程，退化原始林可以恢复为经营原始林，甚至是原始林；相反，如果原始林或经营原始林受到皆伐、火烧等强度人为干扰或火灾、洪水等大规模灾害性自然干扰，导致 90% 的原有森林覆盖消失，之后重新形成的森林则为次生林。次生林通常是在废弃的休耕地、固定农地、牧场或失败的人工造林地上发育而成。通过清除下层林木、补植乡土树种或解放伐等经营措施，在足够长的时间内，次生林可以恢复为退

化原始林。当由于木质或非木质林产品的过度收获、重复火烧、放牧等其他干扰或土地利用完全清除森林覆盖导致土壤严重破坏，森林重建受到抑制或延缓时，此种状态下的林地称为退化林地。经营不当或受到重复火烧等干扰的退化原始林、次生林和人工林都可以转化为退化林地，而退化林地的恢复与重建措施取决于生态、社会、经济、文化等各方面因素，恢复初期的重点应该是采取促进演替的过程，如降低土壤侵蚀度、种植灌木、提高土壤肥力等，而不是立即取代原始林结构或“近自然”物种组成。退化原始林、次生林和退化林地都是超出森林自然过程正常作用而发生变化的森林，统称为退化与次生森林。值得注意的是，这种划分只是对复杂实地的简化，实际上这三种森林状态常存在于不断变化的复杂镶嵌体中，也存在三种状态的中间阶段和/或混合状态。这些状态非常相近，难以区别，但是在制定经营策略时，必须考虑每种状态的特征。

7.1.2 ITTO 对不同森林类别的定义

ITTO 对每种森林类别都给出了详细、明确的定义。

(1)原始林：未受到人类干扰或受到狩猎、采集和伐木的影响非常小，其天然结构、功能和动态过程未发生超过生态系统弹性能力变化的森林。此类森林也包括土著社区和地方社区在符合生物多样性保护和可持续利用的前提下，以传统生活方式而利用的森林。

(2)修正原始林：经营的原始林或为木质和非木质林产品、野生动植物或其他目的而开发利用的原始林，其利用强度越大，偏离原始林结构和组成的程度越大。从生态学上讲，这种偏离常代表向较早演替阶段的转变。

(3)经营原始林：因木质和非木质林产品的可持续收获(如通过综合收获和营林措施)、野生动植物经营和其他利用而改变了原始林最初的森林结构和物种组成，但仍然维持所有主要产品和服务的森林。

(4)退化与次生森林：因森林的不可持续利用或自然灾害，如风暴、火灾、山崩、洪水等，造成森林或林地的变化超出了自然过程的正常作用的森林和林地。与原始林相比，退化与次生森林更容易获取，是许多热带木材生产国主要的林产品来源，也为农村贫困居民提供当前生计所需的生产、社会和保护功能。若得到合理恢复与经营，此类森林能提供原始林所具有的生产功能和环境功能。

(5)退化原始林：在起初有原始林或天然林分覆盖的地区，由于木质和/或非木质林产品的不可持续收获，导致森林结构、过程、功能和

动态的变化超出了生态系统的短期恢复能力的原始林。即此类森林在采伐利用后，已经危害了近、中期内完全恢复的能力，需要主动经营的干预措施才能在短期或中期内恢复生产力和生态系统完整性。

(6)次生林：原有森林植被大面积采伐后(即低于原有森林覆盖的10%)，林地上重新生长的木本植被，通常在废弃轮垦地、固定农业用地、牧场或造林失败地上自然发育而成。特征是早起演替树种组成相对一致(如先锋树种和非先锋喜光树种)、林分年龄相对一致、初期生长快，不具有原始林的所有属性，由于处于早期演替阶段，能对营林措施如解放伐做出很好的反应。

(7)退化林地：原有林地由于木质和/或非木质林产品的过度收获、不合理的经营、反复火灾、放牧或其他损害土壤和植被的干扰或土地利用，而受到了严重破坏，其破坏程度已阻碍或严重推迟了放弃利用后的森林重建工作。其典型特征是土壤贫瘠或易发生土壤侵蚀、水文过程不稳定、林地生产力下降和生物多样性较低、缺乏树种萌芽所需的微环境(外来物种入侵和草本植物占主导地位)，在中短期时间尺度上，持久的物理、化学和生物学限制因素使森林自然演替过程受到抑制。

(8)人工林：通过栽植或播种建立的森林。

(9)荒地造林：无林地上营造的人工林。

(10)更新造林：在天然森林覆盖消失后立即重建林木和林下植被。

(11)补植(辅助更新、补充更新)：在修正天然林或次生林或林地上种植期望树种，目的是建立期望树种(乡土树种和/或高价值树种)占优势的乔木林。

7.2　退化原始林特征

7.2.1　主要优势种的表现

大敢 FLR 示范区退化原始林不同群落类型乔木层植物重要值如表7-1 所示。岭南山竹子、无翼坡垒群落乔木层共有树种 42 种，重要值最大的树种是岭南山竹子，为 41.05%，其次是无翼坡垒，重要值是34.98%；黄杞、粘木、保亭柿、贡甲、橄榄、光叶山矾、尖叶榕的重要值分列第 3 ~9；其他 33 种植物的重要值均小于 10%。黄杞、岭南山竹子群落乔木层植物26 种，其中黄杞的重要值最大，达到70.94%，其次是岭南山竹子和粘木，分别为 55.21% 和 35.50%，光叶山矾、毛果柯、水石梓、榕树、海南黄檀、保亭柿、降香黄檀(花梨)的重要值分

别列第4 ~10。细子龙、岭南山竹子群落乔木层共有35种植物，细子龙的重要值最大，为48.16%，其次是岭南山竹子，重要值为42.14%，黄杞、毛果柯、琼榄、海南大头茶、光叶山矾的重要值分列第3 ~7。水石梓、海南黄檀、海南暗罗群落乔木层共有植物21种，其中水石梓的重要值最大，为33.21%，其次是海南黄檀、海南暗罗、山杜英、过布柿，重要值分列第2 ~5。

4个群落的乔木层树种主要属于大戟科、桑科、山茶科、樟科、壳斗科、柿科、蝶形花科和龙脑香科等，有濒危种特类材降香黄檀（花梨）、渐危种一类材青皮、渐危种特类材荔枝（野生荔枝）、渐危种无翼坡垒、粘木和一类材细子龙等海南珍贵乡土乔木树种。

表7-1 退化原始林不同群落乔木层植物的重要值

群落类型	序号	树种名称		相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
1. 岭南山竹子、无翼坡垒群落	1	岭南山竹子	*Garcinia oblongifolia*	15.61	11.50	13.94	41.05
	2	无翼坡垒	*Hopea exalata*	16.18	12.39	6.41	34.98
	3	黄杞	*Engelhardtia roxburghiana*	5.78	6.19	9.79	21.77
	4	粘木	*Ixonanthes chinensis*	5.78	4.42	6.96	17.17
	5	保亭柿	*Diospyros potingensis*	6.94	5.31	3.84	16.09
	6	贡甲	*Acronychia oligophlebia*	6.36	6.19	2.06	14.61
	7	橄榄	*Canarium album*	4.62	5.31	3.66	13.59
	8	光叶山矾	*Symplocos lancifolia*	2.89	4.42	3.35	10.67
	9	尖叶榕	*Ficus henryi*	1.16	0.88	8.47	10.51
	10	木荷	*Schima crenata*	2.31	2.65	3.64	8.61
	11	黄花木	*Piptanthus laburnifolius*	0.58	0.88	6.73	8.20
	12	台湾枇杷	*Eriobotrya deflexa*	2.89	2.65	2.26	7.80
	13	红绸	*Lithocarpus fenzelianus*	1.73	2.65	2.88	7.27
	14	藜蒴栲	*Castanopsis fissa*	1.73	1.77	3.62	7.12
	15	细子龙	*Amesidodendron chinense*	2.31	2.65	2.05	7.02
	16	榕树	*Ficus microcarpa*	1.73	2.65	1.26	5.65
	17	山乌桕	*Sapium discolor*	1.73	0.88	2.83	5.45
	18	琼榄	*Gonocaryum lobbianum*	1.73	2.65	0.94	5.33

（续）

群落类型	序号		树种名称	相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
1. 岭南山竹子、无翼坡垒群落	19	毛果柯	*Lithocarpus pseudovestitus*	1.16	1.77	2.06	4.98
	20	青皮	*Vatica mangachapoi*	1.16	1.77	0.83	3.76
	21	白树	*Suregada glomerulata*	0.58	0.88	2.19	3.65
	22	猴耳环	*Pithecellobium clypearia*	1.16	1.77	0.70	3.63
	23	黄樟	*Cinnamomum parthenoxylon*	1.16	0.88	0.91	2.95
	24	白毛子楝树	*Decaspermum albociliatum*	0.58	0.88	1.46	2.92
	25	九丁树	*Ficus nervosa*	0.58	0.88	1.31	2.78
	26	猫尾木	*Dolichandrone cauda-felina*	0.58	0.88	1.08	2.54
	27	毛丹	*Phoebe hungmaoensis*	1.16	0.88	0.48	2.52
	28	胭脂	*Artocarpus tonkinensis*	0.58	0.88	0.74	2.21
	29	闽粤石楠	*Photinia benthamiana*	0.58	0.88	0.48	1.94
	30	三叉苦	*Euodia lepta*	0.58	0.88	0.45	1.91
	31	海南大头茶	*Polyspora balansae*	0.58	0.88	0.44	1.90
	32	火桐树	*Erythropsis. colorata*	0.58	0.88	0.43	1.90
	33	水石梓	*Sarcosperma laurinum*	0.58	0.88	0.42	1.88
	34	变叶木	*Codiaeum variegatum*	0.58	0.88	0.28	1.75
	35	丛花厚壳桂	*Cryptocarya densiflora*	0.58	0.88	0.21	1.67
	36	海南蕈树	*Altingia obovata*	0.58	0.88	0.18	1.65
	37	重阳木	*Bischoffia javanica*	0.58	0.88	0.15	1.62
	38	琼南柿	*Diospyros howii*	0.58	0.88	0.14	1.60
	39	荔枝	*Litchi chinensis*	0.58	0.88	0.11	1.57
	40	漆树	*Toxicodendron vernicifluum*	0.58	0.88	0.11	1.57
	41	珊瑚树	*Viburnum odoratissimum*	0.58	0.88	0.10	1.57
	42	野漆树	*Rhus succedanea*	0.58	0.88	0.03	1.50
2. 黄杞、岭南山竹子群落	1	黄杞	*Engelhardtia roxburghiana*	24.62	14.71	31.62	70.94
	2	岭南山竹子	*Garcinia oblongifolia*	22.31	11.76	21.14	55.21
	3	粘木	*Ixonanthes chinensis*	10.00	11.76	13.73	35.50
	4	光叶山矾	*Symplocos lancifolia*	5.38	5.88	3.78	15.04
	5	毛果柯	*Lithocarpus pseudovestitus*	4.62	5.88	2.57	13.07
	6	水石梓	*Sarcosperma laurinum*	3.85	4.41	4.01	12.27
	7	榕树	*Ficus microcarpa*	3.85	4.41	3.16	11.42
	8	海南黄檀	*Dalbergia hainanensis*	2.31	4.41	3.81	10.53
	9	保亭柿	*Diospyros potingensis*	3.08	5.88	1.53	10.49
	10	降香黄檀	*Dalbergia odorifera*	3.85	2.94	3.67	10.46

（续）

群落类型	序号		树种名称	相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
2. 黄杞、岭南山竹子群落	11	海南菜豆树	*Radermachera hainanensis*	2.31	2.94	1.74	6.99
	12	橄榄	*Canarium album*	2.31	2.94	1.34	6.59
	13	厚皮树	*Lannea coromandelica*	1.54	2.94	0.89	5.37
	14	枫香	*Liquidambar formosana*	0.77	1.47	2.93	5.17
	15	木荷	*Schima crenata*	0.77	1.47	0.65	2.89
	16	闽粤石楠	*Photinia benthamiana*	0.77	1.47	0.60	2.84
	17	重阳木	*Bischoffia javanica*	0.77	1.47	0.51	2.75
	18	白树	*Suregada glomerulata*	0.77	1.47	0.46	2.70
	19	贡甲	*Acronychia oligophlebia*	0.77	1.47	0.45	2.69
	20	假苹婆	*Sterculia lanceolata*Cav.	0.77	1.47	0.33	2.57
	21	琼榄	*Gonocaryum lobbianum*	0.77	1.47	0.30	2.54
	22	海南大头茶	*Polyspora balansae*	0.77	1.47	0.22	2.46
	23	皱萼蒲桃	*Syzygium rysopodum*	0.77	1.47	0.18	2.42
	24	厚叶算盘子	*Glochidion dasyphyllum*	0.77	1.47	0.18	2.42
	25	枫木鞘花	*Elytranthe cochinchinensis*	0.77	1.47	0.14	2.38
	26	油楠	*Sindora glabra*	0.77	1.47	0.03	2.27
3. 细子龙、岭南山竹子群落	1	细子龙	*Amesidodendron chinense*	14.29	12.12	21.75	48.16
	2	岭南山竹子	*Garcinia oblongifolia*	17.01	14.14	10.99	42.14
	3	黄杞	*Engelhardtia roxburghiana*	4.76	6.06	7.63	18.45
	4	毛果柯	*Lithocarpus pseudovestitus*	5.44	4.04	7.23	16.71
	5	琼榄	*Gonocaryum lobbianum*	6.12	4.04	6.4	16.56
	6	海南大头茶	*Polyspora balansae*	6.12	6.06	4.18	16.36
	7	光叶山矾	*Symplocos lancifolia*	5.44	7.07	3.16	15.67
	8	大果水翁	*Cleistocalyx conspersipunctatus*	1.36	2.02	7.12	10.50
	9	小叶榕	*Ficus microcarpa*	4.08	3.03	2.47	9.58
	10	海南菜豆树	*Radermachera hainanensis*	3.4	3.03	2.85	9.28
	11	无翼坡垒	*Hopea exalata*	3.4	4.04	0.75	8.19
	12	橄榄	*Canarium album*	2.72	3.03	0.94	6.69
	13	大果木姜子	*Litsea lancilimba*	2.72	2.02	1.7	6.44
	14	粘木	*Ixonanthes chinensis*	2.04	2.02	1.03	5.09
	15	水石梓	*Sarcosperma laurinum*	2.04	2.02	0.66	4.72
	16	华润楠	*Machilus chinensis*	0.68	1.01	1.45	3.14
	17	小叶钓樟	*Lindera playfairii*	1.36	1.01	0.51	2.88
	18	纳槁润楠	*Machilus nakao*	0.68	1.01	1.03	2.72

（续）

群落类型	序号	树种名称		相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
3. 细子龙、岭南山竹子群落	19	五列木	*Pentaphylax euryoides*	1.36	1.01	0.23	2.6
	20	厚壳树	*Ehretia acuminata*	0.68	1.01	0.85	2.54
	21	漆树	*Toxicodendron vernicifluum*	0.68	1.01	0.73	2.42
	22	重阳木	*Bischoffia javanica*	0.68	1.01	0.63	2.32
	23	猴耳环	*Pithecellobium clypearia*	0.68	1.01	0.6	2.29
	24	保亭柿	*Diospyros potingensis*	0.68	1.01	0.48	2.17
	25	油楠	*Sindora glabra*	0.68	1.01	0.36	2.05
	26	闽粤石楠	*Photinia benthamiana*	0.68	1.01	0.36	2.05
	27	台湾枇杷	*Eriobotrya deflexa*	0.68	1.01	0.36	2.05
	28	黄花木	*Piptanthus laburnifolius*	0.68	1.01	0.33	2.02
	29	毛丹	*Phoebe hungmaoensis*	0.68	1.01	0.21	1.9
	30	荔枝	*Litchi chinensis*	0.68	1.01	0.19	1.88
	31	短穗鱼尾葵	*Caryota mitis*	0.68	1.01	0.17	1.86
	32	银珠	*Peltophorum tonkinense*	0.68	1.01	0.16	1.85
	33	大果榕	*Ficus auriculata*	0.68	1.01	0.16	1.85
	34	贡甲	*Acronychia oligophlebia*	0.68	1.01	0.1	1.79
	35	异叶翅子木	*Pterospermum heterophyllum*	0.68	1.01	0.1	1.79
4. 水石梓、海南黄檀、海南暗罗群落	1	水石梓	*Sarcosperma laurinum*	12.82	12.90	7.49	33.21
	2	海南黄檀	*Dalbergia hainanensis*	5.13	6.45	17.99	29.57
	3	海南暗罗	*Polyalthia laui*	12.82	9.68	3.43	25.93
	4	山杜英	*Elaeocarpus sylvestris*	5.13	3.23	16.74	25.10
	5	过布柿	*Diospyros susarticulata*	5.13	6.45	9.66	21.24
	6	毛茶	*Antirhea chinensis*	5.13	6.45	4.72	16.30
	7	岭南山竹子	*Garcinia oblongifolia*	7.69	6.45	1.65	15.80
	8	黄牛木	*Cratoxylum. cochinchinense*	2.56	3.23	8.88	14.67
	9	海南水锦树	*Wendlandia merrilliana*	5.13	6.45	2.27	13.85
	10	变叶榕	*Ficus variolosa*	7.69	3.23	2.64	13.56
	11	万宁柯	*Lithocarpus elmerrillii*	2.56	3.23	7.02	12.81
	12	海南红豆	*Ormosia pinnata*	2.56	3.23	4.04	9.83
	13	烟斗柯	*Lithocarpus corneus*	5.13	3.23	1.19	9.55
	14	赤楠	*Syzygium buxifolium*	2.56	3.23	2.85	8.64
	15	越南牡荆	*Vitex tripinnata*	2.56	3.23	2.85	8.64
	16	白树	*Suregada glomerulata*	2.56	3.23	1.75	7.54
	17	贡甲	*Acronychia oligophlebia*	2.56	3.23	1.56	7.35

（续）

群落类型	序号	树种名称		相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
4. 水石梓、海南黄檀、海南暗罗群落	18	黄杞	*Engelhardtia roxburghiana*	2.56	3.23	1.22	7.01
	19	海南哥纳香	*Goniothalamus howii*	2.56	3.23	0.99	6.78
	20	钝叶木姜子	*Neolitsea obtusifolia*	2.56	3.23	0.74	6.53
	21	乌心楠	*Phoebe henryi*	2.56	3.23	0.30	6.09

7.2.2 群落结构

示范区退化原始林为复层异林龄结构，郁闭度1.0，群落结构较为完整，明显分乔木层、灌木层及草本层。其中乔木层又分为2个亚层，第Ⅰ亚层树高大于8m，第Ⅱ亚层树高小于8 m；由于反复择伐利用等干扰，第Ⅰ亚层价值较高的和干形较好的树木大部分已被利用，现有树木多为直径较小、经济价值不高的树木，例如保亭柿、光叶山矾、猫尾木、九丁树、琼南柿等，但第Ⅱ亚层中仍然有干形较好、生长正常、经济价值较高的珍贵乡土树种，如降香黄檀、无翼坡垒、青皮和野生荔枝等。灌木层物种丰富，主要有降香黄檀、水石梓、海南红豆、万宁柯、猫尾木、丛花厚壳桂、黄杞、海南哥纳香等乔木幼树和药用狗牙花(*Ervatamia officinalis*)、银柴(*Aporosa chinensis*)、白背算盘子、九节等灌木；草本层主要植物是九节、长柄杜英、岭南山竹子、蒲葵(*Livistona chinensis*)、银柴、粘木等乔灌木幼苗和假华箬竹(*Indocalamus latifolius*)、竹节草(*Chrysopogon aciculatus*)等草本植物。此外，退化原始林还有丰富的藤本植物，如菝葜(*Smilax china*)、海南蒟(*Piper hainanense*)和相思子(*Abrus mollis*)等。由此可见，灌木层和草本层仍然有利用价值较高的乔木幼树和幼苗。

7.2.3 乔木层物种多样性

示范区退化原始林不同群落乔木层及各亚层的物种多样性见表7-2。群落1 ~4乔木层物种丰富度R分别为42、26、35和21，多样性指数SW分别为4.46、3.61、4.28和4.14，均匀度指数E分别为0.81、0.77、0.81和0.94，生态优势度ED分别为0.07、0.13、0.07和0.04。

总的来看，示范区退化原始林乔木层物种丰富度R为21 ~42，低于临近地区海南省吊罗山自然保护区内白水林场和南喜林场热带低地雨林的物种丰富度(黄康有等，2007)；多样性指数SW为3.61 ~4.46，与吊罗山自然保护区低海拔热带雨林的物种多样性极为接近(4.04 ~

4.17)，但低于尖峰岭热带原始林的多样性(5.78 ~6.28)(李意德，1997；许涵等，2009)；均匀度指数 E 为 0.77 ~0.94，生态优势度 ED 为 0.04 ~0.13。

表 7-2　退化原始林乔木层物种多样性

群落类型	林层	R	SW	ED	E
群落 1	乔木层	42	4.46	0.07	0.81
	Ⅰ	30	4.39	0.06	0.89
	Ⅱ	29	3.89	0.10	0.80
群落 2	乔木层	26	3.61	0.13	0.77
	Ⅰ	12	2.83	0.18	0.79
	Ⅱ	24	3.73	0.11	0.81
群落 3	乔木层	35	4.28	0.07	0.81
	Ⅰ	25	3.93	0.08	0.85
	Ⅱ	27	2.60	0.10	0.55
群落 4	乔木层	21	4.14	0.04	0.94
	Ⅰ	6	2.50	0.07	0.97
	Ⅱ	15	3.64	0.06	0.93

7.2.4　林分生长

示范区退化原始林林分生长见表 7-3。4 个群落乔木层平均胸径为 10.2 ~ 14.3 cm，平均树高为 8.50 ~ 13.39 m，平均单位面积蓄积量为 142.51 ~ 199.44 m^3/hm^2，明显低于海南霸王岭山地雨林等原始林(蒋有绪和卢俊培，1991；黄清麟，2001；黄清麟等，2002)；林分密度为 2321 ~3545 株/hm^2，大于海南霸王岭山地雨林等原始林。从株树密度和蓄积结构上看，退化原始林株数集中在第Ⅱ亚层，占乔木层株树的 48.30 ~ 79.49%，蓄积量集中在第 Ⅰ 亚层，占总蓄积量的 67.11 ~91.38%。

表 7-3　退化原始林主要测树因子

群落类型	林层	平均胸径 (cm)	平均树高 (m)	密度		蓄积量	
				密度 (株/hm^2)	百分比 (%)	蓄积量 (m^3/hm^2)	百分比 (%)
群落 1	乔木层	12.68	12.33	2595	100	191.55	100
	Ⅰ	17.65	14.23	1005	38.73	164.28	85.77
	Ⅱ	8.09	6.60	1590	61.27	27.27	14.23

（续）

群落类型	林层	平均胸径（cm）	平均树高（m）	密度		蓄积量	
				密度（株/hm^2）	百分比（%）	蓄积量（m^3/hm^2）	百分比（%）
群落2	乔木层	10.20	10.05	3545	100	142.51	100
	Ⅰ	14.29	12.22	1091	30.77	103.30	72.48
	Ⅱ	7.71	6.75	2455	69.23	39.21	27.52
群落3	乔木层	13.16	13.39	2321	100	199.44	100
	Ⅰ	16.79	14.62	1200	51.70	183.17	91.38
	Ⅱ	7.52	6.83	1121	48.30	17.27	8.62
群落4	乔木层	14.30	8.50	2925	100	195.12	100
	Ⅰ	24.06	10.29	600	20.51	130.94	67.11
	Ⅱ	10.74	6.18	2325	79.49	64.18	32.89

7.2.5 林分直径结构

示范区退化原始林直径结构见表7-4和图7-2所示。示范区退化原始林直径分布范围是4～48 cm，最大直径为46.30 cm；由于起测胸径是5cm，因此表7-4和图7-2中4 cm径阶内没有包括胸径为2～4.9cm的林木株数，所以4cm径阶内植物株数比例明显低于8cm径阶。各群落乔木层直径分布呈反J型。

表7-4 退化原始林乔木层直径分布表

径阶（cm）	各径阶株数比例（株）			
	群落1	群落2	群落3	群落4
4	20	17	11	11
8	35	48	36	37
12	24	21	30	23
16	10	7	12	14
20	6	6	5	7
24	3	1	2	4
28	1	0	1	3
32	0	0	2	2
36	0	0	1	0
40	0	0	1	0
44	1	0	0	0
48	1	0	0	0

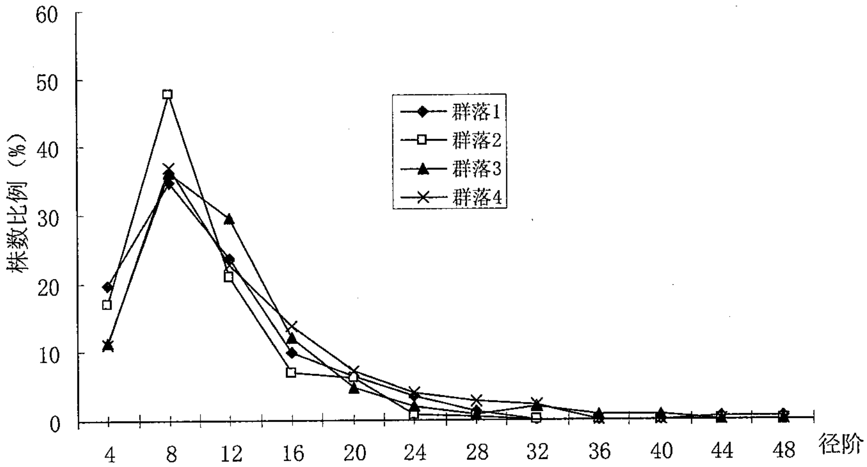

图 7-2　退化原始林乔木层直径分布图

7.3　次生林特征

7.3.1　主要优势种的表现

表 7-5　次生林不同群落植物的重要值

群落类型	序号	树种名称		相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
1. 银柴群落	1	银柴	*Aporosa chinensis*	30.77	12.50	17.05	60.32
	2	烟斗柯	*Lithocarpus corneus*	8.97	6.25	8.36	23.58
	3	岭南山竹子	*Garcinia oblongifolia*	10.26	6.25	5.87	22.38
	4	枫香	*Liquidambar formosana*	2.56	3.13	13.01	18.70
	5	梨果柯	*Lithocarpus howii*	7.69	3.13	4.72	15.54
	6	胭脂	*Artocarpus tonkinensis*	2.56	3.13	9.74	15.43
	7	海南栲	*Castanopsis hainanensis*	2.56	6.25	3.93	12.74
	8	山马耳	*Syzygium buxifolium*	1.28	3.13	7.71	12.12
	9	海南红豆	*Ormosia pinnata*	2.56	6.25	2.90	11.71
	10	单叶豆	*Ellipanthus glabrifolius*	3.85	3.13	4.10	11.07
	11	山乌桕	*Sapium discolor*	1.28	3.13	5.71	10.12
	12	肥荚红豆	*Ormosia fordiana*	2.56	3.13	3.90	9.59
	13	假大青蓝	*Indigofera galegoides*	3.85	3.13	1.95	8.92

（续）

群落类型	序号		树种名称	相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
1. 银柴群落	14	黄牛木	*Cratoxylum. cochinchinense*	2.56	3.13	1.54	7.23
	15	倒吊笔	*Wrightia pubescens*	2.56	3.13	1.12	6.80
	16	琼楠	*Beilschmiedia intermadida*	2.56	3.13	1.01	6.70
	17	厚皮树	*Lannea coromandelica*	1.28	3.13	1.78	6.19
	18	万宁柯	*Lithocarpus elmerrillii*	1.28	3.13	1.23	5.63
	19	谷木	*Memecylon ligustrifolium*	1.28	3.13	1.07	5.48
	20	贡甲	*Acronychia oligophlebia*	1.28	3.13	0.93	5.34
	21	海南黄檀	*Dalbergia hainanensis*	1.28	3.13	0.87	5.27
	22	算盘子	*Glochidion puberum*	1.28	3.13	0.45	4.85
	23	九节	*Psychotria rubra*	1.28	3.13	0.38	4.79
	24	美叶菜豆树	*Radermachera frondosa*	1.28	3.13	0.36	4.76
	25	黑格	*A. odoratissima*	1.28	3.13	0.32	4.72
2. 山黄麻群落	1	山黄麻	*Trema tomentosa*	77.27	37.50	80.32	195.09
	2	假大青蓝	*Indigofera galegoides*	9.09	12.50	10.10	31.69
	3	雁婆麻	*Helicteres hirsuta*	9.09	12.50	3.68	25.27
	4	单叶豆	*Ellipanthus glabrifolius*	1.52	12.50	4.02	18.03
	5	楝叶吴茱萸	*Evodla meliaefolia*	1.52	12.50	1.21	15.22
	6	银柴	*Aporosa chinensis*	1.52	12.50	0.68	14.69
3. 黄牛奶树、海南菜豆树群落	1	黄牛奶树	*Symplocos laurina*	29.67	20.00	28.72	78.39
	2	海南菜豆树	*Radermachera hainanensis*	23.08	10.00	25.67	58.75
	3	闽粤石楠	*Photinia benthamiana*	9.89	5.00	11.00	25.89
	4	麻楝	*Chukrasia tabularis*	7.69	15.00	2.37	25.06
	5	厚皮树	*Lannea coromandelica*	6.59	10.00	5.35	21.94
	6	白背算盘子	*Glochidion wrightii*	4.40	10.00	5.27	19.67
	7	白树	*Suregada glomerulata*	8.79	5.00	5.50	19.29
	8	多瓣核果茶	*Parapyrenaria multisepala*	2.20	5.00	9.78	16.98
	9	三叉苦	*Euodia lepta*	3.30	5.00	2.06	10.36
	10	厚叶算盘子	*Glochidion dasyphyllum*	2.20	5.00	2.44	9.64
	11	美叶菜豆树	*Radermachera frondosa*	1.10	5.00	1.22	7.32
	12	油楠	*Sindora glabra*	1.10	5.00	0.61	6.71

（续）

群落类型	序号		树种名称	相对多度（%）	相对频度（%）	相对优势度（%）	重要值（%）
4. 毛果柯群落	1	毛果柯	*Lithocarpus pseudovestitus*	19.63	5.66	23.38	48.67
	2	假苹婆	*Sterculia lanceolata*	8.59	5.66	6.25	20.50
	3	山乌桕	*Sapium discolor*	8.59	3.77	5.27	17.63
	4	橄榄	*Canarium album*	3.68	3.77	6.71	14.16
	5	谷木	*Memecylon ligustrifolium*	4.29	1.89	7.58	13.76
	6	厚叶算盘子	*Glochidion dasyphyllum*	4.29	3.77	4.42	12.48
	7	油楠	*Sindora glabra*	4.29	5.66	1.16	11.12
	8	白树	*Suregada glomerulata*	3.07	3.77	3.89	10.73
	9	白背算盘子	*Glochidion wrightii*	2.45	3.77	3.90	10.13
	10	海南红豆	*Ormosia pinnata*	3.68	5.66	0.64	9.98
	11	九节	*Psychotria rubra*	3.68	5.66	0.55	9.89
	12	山麻树	*Commersonia bartramia*	3.68	3.77	2.06	9.51
	13	岭南山竹子	*Garcinia oblongifolia*	0.61	1.89	6.77	9.27
	14	水石梓	*Sarcosperma laurinum*	2.45	1.89	4.55	8.89
	15	倒吊笔	*Wrightia pubescens*	1.84	3.77	3.20	8.81
	16	算盘子	*Glochidion puberum*	3.07	3.77	1.44	8.28
	17	猫尾木	*Dolichandrone cauda-felina*	1.84	1.89	2.85	6.58
	18	榕树	*Ficus microcarpa*	1.84	3.77	0.97	6.58
	19	厚皮树	*Lannea coromandelica*	2.45	1.89	1.69	6.03
	20	黄杞	*Engelhardtia roxburghiana*	1.84	3.77	0.32	5.94
	21	黄樟	*Cinnamomum parthenoxylon*	1.23	3.77	0.53	5.53
	22	八角枫	*Alangium chinense*	1.23	1.89	2.41	5.52
	23	黄牛奶树	*Symplocos laurina*	1.23	1.89	2.41	5.52
	24	三叉苦	*Euodia lepta*	1.23	1.89	1.90	5.02
	25	长柄杜英	*Elaeocarpus petiolatus*	2.45	1.89	0.42	4.76
	26	楝叶吴茱萸	*Evodla meliaefolia*	0.61	1.89	1.69	4.19
	27	海南菜豆树	*Radermachera hainanensis*	1.23	1.89	1.02	4.14
	28	细子龙	*Amesidodendron chinense*	1.84	1.89	0.07	3.80
	29	异叶翅子木	*Pterospermum heterophyllum*	0.61	1.89	1.08	3.58
	30	桂木	*Artocarpus lingnanensis*	1.23	1.89	0.08	3.19
	31	麻楝	*Chukrasia tabularis*	0.61	1.89	0.66	3.16
	32	丛花厚壳桂	*Cryptocarya densiflora*	0.61	1.89	0.15	2.65

示范区次生林不同群落类型乔木层树种重要值如表7-5所示，其中黄牛奶树、海南菜豆树群落和毛果柯群落采用地径代替胸径来计算相对优势度，并由此计算重要值。银柴群落乔木层共有树种25种，其中银柴的重要值最大，为60.32%，其次是烟斗柯和岭南山竹子，重要值分别为23.58%和22.38%，枫香、梨果柯、胭脂、海南栲、山马耳、海南红豆、单叶豆和山乌桕的重要值分列4~11，其他14种植物的重要值均小于10%。山麻黄群落乔木层共有树种6种，其中山麻黄的重要值最大，达到195.09%，假大青蓝、雁婆麻、单叶豆、楝叶吴茱萸和银柴的重要值依次减小。黄牛奶树、海南菜豆树群落乔木层共有树种12种，黄牛奶树重要值最大，为78.39%，其次是海南菜豆树，重要值为58.75%，闽粤石楠、麻楝和厚皮树的重要值分列第3~5。毛果柯群落乔木层共有32种不同树种，重要值最大的是毛果柯，为48.67%，其次是假苹婆，为20.50%，山乌桕、橄榄、谷木、厚叶算盘子、油楠、白树、白背算盘子和海南红豆的重要值依次减小，分列3~9，其他23种树种的重要值均小于10%。

4个群落的乔木层树种主要属于大戟科、壳斗科、榆科、紫葳科、梧桐科和蝶形花科等，有一类材麻楝和细子龙等海南珍贵乡土树种，也有海南红豆、厚皮树和岭南山竹子等用于制作门、窗、农具、家具的用材树种，还有海南重要商品材树种山黄麻等和适用于荒山荒地造林的猫尾木等树种。

7.3.2 群落结构

示范区次生林群落结构简单，郁闭度1.0。相比退化原始林，次生林群落结构分化较不明显，所调查的四个群落中，银柴群落和山麻黄群落乔木层和灌木层分化较为明显，而黄牛奶树、海南菜豆树群落和毛果柯群落不明显。总的来看，次生林群落主要有银柴、烟斗柯、枫香、胭脂、山黄麻、海南菜豆树、毛果柯、假苹婆、白楸和胭脂等乔木树种和雁婆麻、厚叶算盘子、猫尾木、白背算盘子、九节和黄牛木等灌木树种。草本层物种丰富，草本盖度达100%，主要是银柴、三叉苦、九节、山麻黄、海南红豆、毛柿(*Diospyros strigosa*)、刺篱木(*Flacourtia indica*)、贡甲、白楸、滨木患(*Arytera littoralis*)、倒吊笔、乌心楠(*Phoebe henryi*)和山乌桕等乔灌木幼苗，以及竹节草(*Chrysopogon aciculatus*)、三荚草等草本植物。次生林群落中的藤本植物也较为丰富，如菝葜(*Smilax china*)、鱼藤(*Papilionaceae*)、野葛(*Pueraria lobata*)、相思子(*Abrus mollis*)等。由此可见，次生林群落仍然有利用价值较高的乔

木幼树和幼苗。

7.3.3　乔木层物种多样性

对林分乔木层物种多样性测定结果(表7-6)表明：不同示范区群落乔木层物种多样性差异明显，乔木层物种丰富度R分别为25、6、24和32，多样性指数SW分别为3.79、1.19、2.94和4.41，均匀度指数E分别为0.82、0.46、0.82和0.88，生态优势度ED分别为0.12、1.00、0.16和0.07。与退化原始林相比，示范区次生林表现出较低的物种丰富度和较高的生态优势度。

表7-6　次生林林分特征①

项目	群落1	群落2	群落3	群落4
乔木层物种丰富度R	25	6	24	32
乔木层多样性指数SW	3.79	1.19	2.94	4.41
乔木层均匀度E	0.82	0.46	0.82	0.88
乔木层生态优势度ED	0.12	1.00	0.16	0.07
平均胸径(DBH/cm)	6.44	4.48	—	—
平均树高(H/m)	5.23	4.74	—	—
平均密度($N/N\cdot hm^{-2}$)	5850	6600	6828	8300
平均蓄积量($V/m^3\cdot hm^{-2}$)	10.12	26.09	—	—

①：未调查黄牛奶树、海南菜豆树群落和毛果柯群落的胸径。

7.3.4　林分生长

示范区次生林林分生长如表7-6所示。银柴群落和山黄麻群落乔木层平均胸径分别为6.44 cm和4.48cm，平均树高分别为5.23 m和4.74m，平均单位面积蓄积量分别为10.12 m^3/hm^2和26.09 m^3/hm^2，明显低于示范区退化原始林。4个群落林分密度为5850～8300株/hm^2，大于示范区退化原始林的林分密度。

7.3.5　林分直径结构

以银柴群落和山黄麻群落的直径分布(见图7-3)说明示范区次生林直径结构。示范区次生林直径分布范围是2～16 cm，最大直径为15.80 cm，呈反J型直径分布。

7.4　退化林地特征

2009年3月调查了示范区内1个退化林地群落类型，设置了一个面积为360 m^2的带状样地，样地由10个6 m×6 m的小样方组成，测定每个样方内所有林木的物种名称、树高。所调查的退化林地有零星的乔木

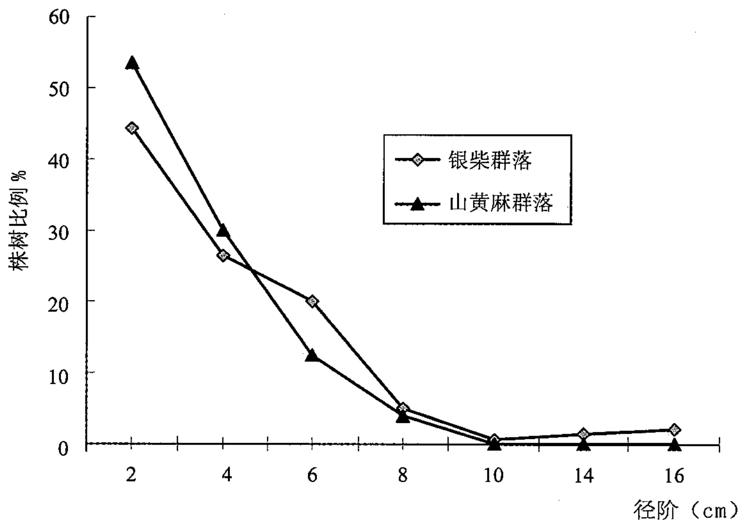

图 7-3 次生林乔木层直径分布图

和灌木分布(表7-7)，高度在0.5 ~2 m之间。

表 7-7 退化林地主要树种

序号		树种	备注	序号		树种	备注
1	银柴	*Aporosa chinensis*	乔木	13	毛茶	*Antirhea chinensis*	灌木
2	假苹婆	*Sterculia lanceolata*	乔木	14	粉叶菝葜	*Smilax corbularia*	灌木
3	土蜜树	*Bridelia monoica*	乔木	15	大管	*Micromelum falcatum*	灌木
4	刺篱木	*Flacourtia indica*	乔木	16	刺轴榈	*Licuala spinosa*	灌木
5	笔管榕	*Ficus virens*	乔木	17	琼榄	*Gonocaryum lobbianum*	乔木
6	海南苹婆	*Sterculia hainanensis*	乔木	18	破布叶	*Microcos paniculata*	乔木
7	滨木患	*Arytera littoralis*	乔木	19	毛柿	*Diospyros strigosa*	乔木
8	鸡爪簕	*Randia sinensis*	灌木	20	黄牛木	*Cratoxylum. cochinchinense*	乔木
9	海南狗牙花	*Ervatamia hainanensis*	灌木	21	海南血桐	*Macaranga hemsleyana*	乔木
10	海南巴豆	*Croton laui*	灌木	22	短穗鱼尾葵	*Caryota mitis*	小乔木
11	多刺山黄皮	*Randia depauperata*	灌木	23	海南五层龙	*Salacia hainanensis*	藤本
12	山油柑	*Acronychia pedunculata*	灌木				

7.5 立地水平恢复策略

7.5.1 退化原始林恢复

大敢 FLR 示范区退化原始林是原始林经过多次择伐利用后形成的，目前主要分布在南部和东南部的山顶区域。特征研究表明，退化原始林

仍然保留了早先原始林的主要特征，如树种组成、土壤结构、林分结构等，仍然具有重要的生态保护功能，因此恢复的基本原则是去除森林退化的原因，利用森林的自然演替过程恢复退化原始林。

天然恢复是指在保护的基础上依靠自然演替的力量来恢复天然林。为了确保天然恢复成功，关键是要确定被保护的对象林分或地段，要求选择有种子或无性繁殖体，或附近有来源的林地。示范区退化原始林为复层异林龄结构，郁闭度 1.0，群落结构较为完整，明显分乔木层、灌木层及草本层。乔木层中仍然有干形较好、生长正常、经济价值较高的珍贵乡土树种，如降香黄檀、无翼坡垒、青皮和野生荔枝等。灌木层和草本层物种丰富，有价值较高的乔木幼树和幼苗，具有丰富的物种储备，如灌木层主要有降香黄檀、水石梓、海南红豆、万宁柯、猫尾木、丛花厚壳桂、黄杞、海南哥纳香等乔木幼树和药用狗牙花、银柴、白背算盘子、九节等灌木；草本层有九节、长柄杜英、岭南山竹子、蒲葵、银柴、粘木等乔灌木幼苗。因此，退化原始林属于轻度退化的森林，具备天然更新的能力，只要对需要恢复的立地采取封山育林的方式以保证群落自然恢复，主要包括封山、禁伐、禁猎等封禁性保护措施，避免进一步的干扰，如毁林、木材和非木材林产品的过度收获等，就可以依靠群落的天然更新和自然演替过程实现生态系统生物多样性、结构、功能和生产力的恢复，促进退化原始林向经营原始林、甚至是原始林的转变。该策略也称为"被动恢复"(Grieser Johns A，1997)，尤其适用于对森林景观恢复活动的财政支持有限的情况，是低成本且能够在大面积范围内推广应用的策略之一。在退化原始林、次生林林分与人工林、退化林地或农地的边界上种植马占相思、桉树等速生树种作为绿色隔离带，可以有效界定退化原始林与次生林，避免进一步的人为干扰。

7.5.2 次生林经营

示范区次生林的权属有两种：由退化原始林皆伐后自然演替形成的次生林为集体所有；皆伐用于农作物种植后、荒弃 10 年以上形成的次生林归原开发户主所有，为村民个人所有。权属不同，恢复措施和需要解决的冲突也不同。

集体所有的次生林，如黄牛奶树、海南菜豆树群落和毛果柯群落，乔木层含有一类材麻楝和细子龙等海南珍贵乡土树种，也有海南红豆、厚皮树和岭南山竹子等用于制作门、窗、农具、家具的用材树种，因此采取与退化原始林相同的恢复措施——保护性"减压"，建立绿色隔离带，尽量阻断人为干扰，利用现有幼树、幼苗，实现天然恢复。个人所

有的次生林，如银柴群落和山麻黄群落，其中有重要商品材树种山黄麻、海南红豆等和适用于荒山荒地造林的猫尾木等树种，但是缺乏珍贵乡土树种，因此这类次生林的恢复采取保护与补植相结合的措施，利用现有幼树、幼苗进行保护性恢复，再加上补植珍贵乡土树种，尽可能利用乡土树种定向恢复以高经济价值林木为目标的森林群落，以提高生态完整性和社区居民福利。

树种的选择是森林恢复的基础，选择既有良好的生态适应性，又有较好的经济、生态功能适宜性的建群树种是补植成功的关键。补植树种的选择需要征求当地社区居民的建议，本研究通过村民大会、居民访谈等参与式过程，获得社区居民喜爱的树种排序：降香黄檀、土沉香、马占相思，因降香黄檀和土沉香的木材珍贵且是示范区的乡土树种，因此选择降香黄檀、土沉香作为研究区次生林的主要补植树种。两种常用补植方法是线状补植和林缝补植，选择依据是林分的条件、恢复目标和所用树种的更新情况。在退化、过伐林区适合用林隙补植，如果林分内周围树木很小(少于 10cm dbh)，适合用线状补植。

恢复集体所有的次生林面临的最大冲突即是如何减少村民为扩大人工林种植的干扰，具体恢复措施的实施，如树种选择，不需要与每户居民进行协商，而仅让居民明白这类次生林的生态功能，自觉遵守“禁伐”的规定；个人所有的次生林，其恢复中所面临的最大冲突是保留次生林还是开发为人工经济林，并且决定权在于村民，也就是说这类次生林随时都面临再次开发的干扰，具体恢复活动的实施如树种选择必须与林地所有者进行反复协商，选择村民能接受的珍贵乡土树种，以便在经济收益与生态服务间找到均衡点，即满足森林景观恢复的“双重过滤器”原则。否则，村民不会将自己因荒弃形成的次生林，且地力又恢复了一段时间，用于专门的生态建设，而仍然会将其开发为经济效益较高的人工经济林。

为体现次生林经营的多重性，皆伐后形成的次生林，因集体性质而不存在具体的利益冲突对象，经营应以提供环境服务为主要目标，其中的林产品主要用于补充生活能源的薪柴需求；开垦荒弃后形成的次生林，因归于不同村民所使用，恢复时存在经济收益与生态服务间的冲突，其经营目标可适当偏重经济收益方面，即在恢复生态完整性的同时，尽量增加村民收入。

7.5.3 退化林地重建

退化林地应该是重建为主，即人工造林，在人工造林过程中尽可能

保留残留的天然幼树。特征研究表明，所调查的退化林地土壤条件较好，但是只有很少的乔木幼树幼苗，如果依靠封禁措施恢复退化林地，则需要相当长的时间，因此应采取人工造林为主的重建策略。对于土壤条件差、碎石较多、经常遭受人为扰动、坡度陡的严重退化林地，出于经济或技术原因，需要首先种植生长快、抗旱、耐热、抗病虫害、经济价值较高的先锋树种作为保育木，必要时采用外来树种，如桉树、马占相思等，改良土壤，然后在下层种植珍贵乡土树种，如降香黄檀、土沉香等，下层林木生长起来后砍伐保育木，增加苗木所需光照。通过这种方式，既能加速退化林地生态系统的重建，又能提高当地村民的收入。

7.6 小　结

本章在充分理解不同森林类别的界定的前提下，以海南省陵水黎族自治县大敢 FLR 示范区退化与次生森林为对象，从森林经营角度探讨其林分特征，并根据林分特征提出了具体的立地水平恢复策略。

(1)ITTO 将森林划分为原始林、修正天然林和人工林，修正天然林又分为经营原始林、退化与次生森林，其中退化与次生森林是超出森林自然过程正常作用而发生变化的森林，包括退化原始林、次生林和退化林地。不同森林类别之间存在一个动态变化的过程，各类森林相互联系，在一定条件下可以相互转化。退化原始林、次生林、退化林地通常处于不断变化的复杂镶嵌体中，在制定具体的经营策略时，必须考虑每种状态的特征。

(2)大敢 FLR 示范区退化原始林林分平均胸径、平均树高和平均单位面积蓄积量分别为 10.2 ~14.3 cm、8.50 ~13.39 m 和 142.51 ~ 199.44 m^3/hm^2，且乔木层第Ⅰ亚层(树高大于 8m)价值较高的和干形较好的树木大部分已被利用，所调查的 4 个群落主要优势树种分别为岭南山竹子和无翼坡垒、黄杞和岭南山竹子、细子龙和岭南山竹子，以及水石梓、海南黄檀和海南暗罗。从群落结构、外貌和物种多样性来看，退化原始林的某些特征与原始林相同，群落结构较为完整，郁闭度大，明显分乔木层、灌木层及草本层；乔木层树种丰富，表现出较高的物种多样性(SW 为 3.61 ~4.46)，与邻近地区吊罗山自然保护区低海拔热带雨林的物种多样性接近(4.04 ~ 4.17)；直径分布呈反 J 型；林分密度(2321 ~3545 株/hm^2)大于海南霸王岭山地雨林和原始林；乔木层第Ⅱ亚层中仍然有干形较好、生长正常、经济价值较高的珍贵乡土树种，如濒危种特类材降香黄檀(花梨)、渐危种无翼坡垒和渐危种一类材青皮、

渐危种特类材荔枝(野生荔枝)、渐危种粘木和一类材细子龙等海南珍贵乡土乔木树种；灌木层和草本层仍然有价值较高的乔木幼树和幼苗。

(3)4个次生林群落优势树种分别为银柴、山麻黄、黄牛奶树和海南菜豆树、毛果柯，群落结构简单，郁闭度1.0，林分密度为5850～8300株/hm^2，乔木层树种主要属于大戟科、壳斗科、榆科、紫葳科、梧桐科和蝶形花科等，有一类材麻楝和细子龙等海南珍贵乡土树种，海南红豆、厚皮树和岭南山竹子等用材树种，以及海南重要商品材树种山黄麻等和适用于荒山荒地造林的猫尾木等树种。其中银柴群落和山黄麻群落乔木层平均胸径分别为6.44 cm和4.48cm，平均树高分别为5.23 m和4.74m，平均单位面积蓄积量分别为10.12 m^3/hm^2和26.09 m^3/hm^2，明显低于示范区退化原始林；直径分布范围是2～16 cm，呈反J型直径分布。相比退化原始林，次生林群落结构分化较不明显，表现出较低的物种丰富度和较高的生态优势度。

(4)示范区退化原始林是原始林经过多次择伐利用后形成的，主要分布在南部和东南部的山顶区域，以保护和促进天然更新为主要恢复策略，通过各种封禁措施，保护现存林木及其更新幼树幼苗，依靠群落的天然更新和自然演替过程恢复退化原始林。立地水平的次生林采取保护与补植相结合的经营策略：集体所有的次生林，乔木层含有珍贵乡土树种，采取保护性“减压”；个人所有的次生林，其中有重要商品材树种和适用于荒山荒地造林树种，但是缺乏珍贵乡土树种，实施保护与补植相结合的措施，利用现有幼树、幼苗进行保护性恢复，同时补植珍贵乡土树种，如降香黄檀、土沉香等，尽可能利用乡土树种定向恢复以高经济价值林木为目标的森林群落。退化林地应该是重建为主，即人工造林，在人工造林过程中尽可能保留残留的天然幼树。促进退化与次生森林有效保护的措施之一是种植绿色隔离带。

第八章　参与式农村评估(PRA)的应用

森林景观恢复是一个过程，它通过所有利益相关者的相互合作，协调利益相关者之间的土地利用，共同制定技术上可行、经济上合理、社会可接受的恢复方案，从而恢复生态完整性，提高居民福利。这一过程有三个原则：参与式；建立在适应性经营的基础上，及时对社会、经济、环境的变化做出响应；需要一个清晰、持续的评价和学习框架。其中“参与”贯穿于森林景观恢复的整个过程，从资料收集、利益相关者确定、格局分析、驱动力分析到优先恢复立地的选择、立地水平恢复措施的实施等都需要强调公众参与。作为森林景观恢复区别于其他恢复方法的重要体现之一，有意义的公众参与是实施森林景观恢复的基础和前提，也是成功实施森林景观恢复的关键。

参与式农村评估(participatory rural appraisal，PRA)是国际上 20 世纪 90 年代初发展起来并迅速推广运用的农村社会调查研究方法，作为一种新的思维和新的方法，其充分强调受益者作为项目活动主题的重要性，并重视受益者能力的提高，它可以由开始的问题识别贯穿到项目实施、监测、评估的整个过程，近年来 PRA 的科学性和可操作性已经被越来越多的从事农业研究和农业综合开发项目的人员所接受，已广泛运用于自然资源管理(水土保持、林业、渔业、野生动物保护、村社规划等)、农业生产、扶贫项目及卫生保健项目等(刘金龙等，1999；任晓冬等，2002；赵杰等，2003；刘磊等，2004；张志等，2005；黄文娟等，2005；符史杭等，2006；徐建英等，2006，刘金龙等，2006，Malley 等，2006)。

本章以大敢 FLR 示范区为例，通过 PRA 工具的应用，结合社区水平 FLR 规划与实施过程，研究 PRA 方法在森林景观恢复中的应用技术。

8.1　PRA 工具的应用

社区水平森林景观恢复是一个社区利益相关者共同分析森林景观问题和制定森林景观恢复规划，以实现恢复社区生态完整性和提高居民福利的过程。本研究采用了直接观察、村民大会、森林调查、大事记、半结构访谈、特殊群体讨论会(穷人、妇女等)、参与式制图、问题矩阵

排序、村民需求评估等 PRA 工具，本部分重点阐明村民大会、实地踏查、参与式森林调查、半结构访谈和矩阵排序等 PRA 工具在社区森林景观恢复中的应用。

除了用于社区水平，PRA 方法的各种工具也在区域水平 FLR 中得到了应用，重点是小组会议、实地踏查、半结构访谈、矩阵排序等工具。总的来说，从资料收集、利益相关者确定、格局分析、驱动力分析到优先恢复立地的选择、立地水平恢复措施的实施等森林景观恢复的内容中都用到了 PRA 方法。

8.1.1 村民大会

分别于2008 年5 月、2009 年3 月和2009 年5 月在大敢 FLR 示范区召开村民大会。首次村民大会的主要目的是让森林景观恢复工作家喻户晓，取得社区村民的配合，激励村民积极参与，并找出当前社区存在的主要困难和村民认为的解决办法。在乡负责人的帮助下于 2008 年 5 月 14 日召开，共有 171 人(每户家庭至少一人)参加，其中妇女 68 人。这次村民大会向村民介绍的内容包括：①概况介绍开展社区 FLR 的目的、背景和内容；②介绍 FLR 工作小组成员，表明各自的态度；③介绍 FLR 工作小组的目的与任务，活动安排；④需要村民如何协助、参与等；⑤让村民推举可协助 FLR 工作的村民代表。第二次村民代表大会在实地踏查和参与式森林调查(小班区划与小班调查)之后于 2009 年 3 月 24 日召开，目的是核实小班的边界和权属(户主)，并将初步森林景观恢复规划反馈给村民，及时修正 FLR 规划。由于这次村民大会需要确定优先恢复立地，主要是退化原始林和次生林等集体所有的林地，因此本次大会共有 421 人参加，其中妇女 156 人，满足 2/3 以上村民参加会议的要求。针对人数较多、不便组织的问题，大会分成 3 个村民小组分别召开。会议内容包括社区存在问题、原因和解决办法，村民喜爱的树种排序，核对景观镶嵌图(林业基本图)，确定优先恢复立地的权属等。第三次村民大会在实施立地水平恢复措施之前于 2009 年 5 月 26 日召开，目的是向村民反馈立地水平恢复措施，村民表决通过社区 FLR 规划，并签订实施恢复措施的相关合同。共有 154 人参加，其中妇女 53 人，同时保证了每户家庭至少一人参加大会。

8.1.2 实地踏查

以地形图和地籍图等图面资料和解译后的遥感影像为基础，通过实地走访，直接观察和村民访问，获取景观镶嵌体每一斑块的土地利用现状、权属、土地利用历史和未来可能的利用方式等信息，应用差分 GPS

进行每个斑块的定位。踏查时间主要集中在2008年11～12月、2009年3～4月，目的是分解村民小组权属边界、景观要素类型边界，为景观格局分析提供基础数据。具体步骤包括：①寻找既有知识又愿意合作的主要知情者，如村民小组长、前任护林员等；②与主要知情者充分讨论后，确定踏查路线；③沿路线踏查走访，在田间地头与村民进行交流、讨论；④与主要知情者一起划分斑块边界，结合农户走访，注明斑块具体信息；⑤与主要知情者共同检查斑块边界，绘制不同时期景观镶嵌图。

8.1.3　参与式森林调查

在全面踏查的基础上，进行小班区划和小班调查，同时选择典型的退化与次生森林进行群落学和测树学特征调查。调查人员必须包括至少一名主要知情者(或村民代表)，既能充分利用主要知情者的乡土知识，又能帮助村民理解生物多样性保护和持续利用现有森林资源的重要性，从而进一步协助村民分析当前森林资源利用活动中存在的问题和可能采取的对策等。经验表明当地居民非常关心如何利用森林维持和改善他们的日常生活，以及能够从森林中获益和利用森林资源的权利保障等问题，社区内部对森林资源的利用有村规民约的约束，村民之间不存在森林利用上的冲突，对森林资源的竞争发生在政府和社区之间以及不同社区的森林利用者之间。

8.1.4　半结构访谈

针对实地踏查和森林调查中发现的问题，采用半结构访谈的方式，围绕森林退化和森林恢复的主题，对单个农户进行访谈。半结构访谈主要用于完成四个内容：小班边界和权属的确定与核对、分析景观格局变化的驱动力、森林经营中存在的问题和期望的解决办法、优先恢复立地不同恢复措施的协商。根据访谈的目的和主题，分析可能相关的因素，形成次级主题，并在访谈中利用次级主题讨论问题。半结构访谈还是获取居民社会经济情况的重要工具。

8.1.5　矩阵排序

通过村民大会、森林考察、半结构访谈、特殊群体讨论会、参与式制图等步骤，收集到足够的信息和一大堆问题的罗列。这时应将所收集到的资料和信息进行整理、归类和分析，找出其内在的关系和可能导致的结果，并将存在问题按严重程度和主次顺序排列出来，初步分析出解决这些问题可能的途径、对策和方法。由于每个人都有不同的个人喜好、知识阅历和生活经验，导致人们对一些事物即使是相同事物也会持

有不同的看法和观点。矩阵排序是根据一定的要求对调查事务进行排比评分，目的是掌握外业调查和居民访谈时遇到不同组别的人对树种选择、存在困难和社区发展规划等问题的不同看法，从而做出能代表大多数人意见的判断。矩阵排序主要是在村民大会上用于收集村民对某一事务的看法和意见，并能通过村民的反馈意见及时修改矩阵排序，获得树种选择、存在困难和原因、愿景等问题的排序。

8.2 结果分析

8.2.1 自然资源概况

大敢村隶属于陵水黎族自治县群英乡光国行政村，面积 399.48 hm^2，土地资源丰富。属热带季风岛屿性气候，雨量充沛、光温条件好、气候适宜，非常适合发展多种热带经济作物和畜牧业。花岗岩深度风化的壤土深厚且多砂，也适宜林、园等木本植物生长。共有大小水塘 5 处，并且村西有条贯穿南北的小溪注入主干河道陵水河，为沿河农林业发展提供灌溉用水。

二十年前，天然林资源十分丰富，后因采伐天然林种植橡胶、“刀耕火种”和乱砍滥伐等原因，天然林面积急剧减少；到 20 世纪 90 年代初，除丘陵顶部和离居民点较远的南部保存有较为完整的退化原始林和次生林外，地势较平坦、水源较好或离居民点较近的天然林被橡胶林、木薯地、荔枝和杧果等经济林，以及灌木林和退化林地所取代。

现有天然林 89.61 hm^2，人工林 240.30 hm^2。天然林主要是退化原始林和次生林，面积分别为 42.06 hm^2、47.55 hm^2。退化原始林群落中仍然有干形较好、生长正常、经济价值较高的珍贵乡土树种，如降香黄檀、无翼坡垒、青皮和野生荔枝等和水石梓、海南红豆、万宁柯、猫尾木、丛花厚壳桂、黄杞、海南哥纳香等海南常见树种。次生林群落有一类材麻楝和细子龙等海南珍贵乡土树种，也有海南红豆、厚皮树和岭南山竹子等用于制作门、窗、农具、家具的用材树种，还有海南重要商品材树种山黄麻等和适用于荒山荒地造林的猫尾木等树种。人工林树种主要是槟榔、橡胶、桉树，面积分别为 166.36 hm^2、45.86 hm^2 和 10.02 hm^2。其中树龄低于 5 年的人工林面积为 151.70 hm^2，树龄 10 年以上人工林 57.70 hm^2，而 6 ~9 年的仅 32.20 hm^2。树龄 10 年以上的橡胶、槟榔都已处于盛产期。

天然林中可利用非木材林产品种类多样，药用植物有抗病原微生物的土蜜树、山乌桕、野葛等，治疗神经系统疾病、增强机体免疫作用的

牛大力(*Millettia speciosa*)等、治疗跌打损伤的假苹婆、鱼藤(*Papilionaceae*)等；果类资源有龙眼、野荔枝、大果水翁、猪肚木(*Canthiun horridum*)等；芳香植物资源有麻楝等；此外，可用于观赏的灌木鱼尾葵(*Caryota ochlandra*)分布广泛。

8.2.2　社会经济概况

大敢村属典型的黎族聚居区，分为芬优、芬界、大干三个村民小组。2009 年全村共有 134 户、586 人(皆为黎族)，男 348 人、女 259 人，共有劳动力 414 人。其中芬优村小组有 64 户、228 人、劳动力 151 人，芬界村小组有 40 户、186 人、劳动力 110 人，大干村小组有 60 户、224 人、劳动力 153 人。出售橡胶、槟榔是其主要收入来源，2009 年人均纯收入 750 元左右(如图 8-1)。2009 年共有 134 人外出打工，大多为青年。

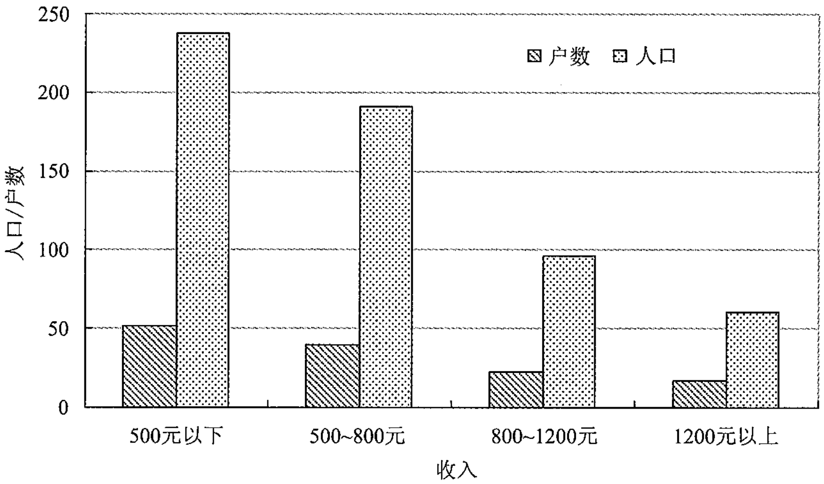

图 8-1　大敢村人均年纯收入的人口和户数分布

粮食作物以水稻为主，辅以玉米和红薯。水稻为一年两季或一季。近年来由于刀耕火种、管理投入等人为活动的扰动，地表覆盖物的减少，以及当地土壤较强的砂质性，导致雨季时水土流失严重。同时，因降雨的季节性和水土流失诱发的坑塘淤积，导致社区多数两季田因春季缺水而旱稻不能种植，6 ~ 7 月份雨季到来时才能种植一季。目前全村每户平均水田面积 66.7m^2(0.0067hm^2)，集中分布于周围低山环抱的盆地区。旱地地没有明确划分，通过到村子周围的山上烧荒而开发，大多种植木薯用以出售，只有少数种玉米、红薯。农户的大多劳作还处于刀耕火种阶段，通常将一片山林砍掉，炼山后再进行作物种植。

农事安排方面，见表8-1农事季节历。

表8-1 大敢村居民农业生产季节历

农作物	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
红薯		种植						收获	收获			
橡胶	除草	施肥	除草	割胶	割胶	割胶	割胶	割胶	割胶	割胶	割胶	施肥
槟榔				开花						收获	收获	施肥
早稻	施肥		施肥	收获								种植
晚稻					种植	施肥		施肥	收获			
芒果	开花				收获 剪枝	除草	施肥					
木薯				种植								收获
玉米				种植		收获	收获					
瓜菜		收获	收获								种植	施肥、灌溉

交通与文化教育方面，大敢村内公路不通，交通闭塞，只有一条路面差、未经硬化、约2.5km长的村级公路通向乡村公路，晴通雨阻，不利于农用物资的运输、科技信息的流通等，村中街道均未硬化，主要交通工具为二轮摩托车，平均每户一辆。村内居民受教育程度不均，35岁以下多为初中文化程度，35～55岁多为小学文化程度，55岁以上多为文盲，另村中有2名大专生(图8-2)。适龄儿童要到乡政府驻地上学，收入高的家庭到县城的学校上学。村内无专业医疗人员和赤脚医生，需到乡镇卫生所、附近南平农场和县城医院就医。

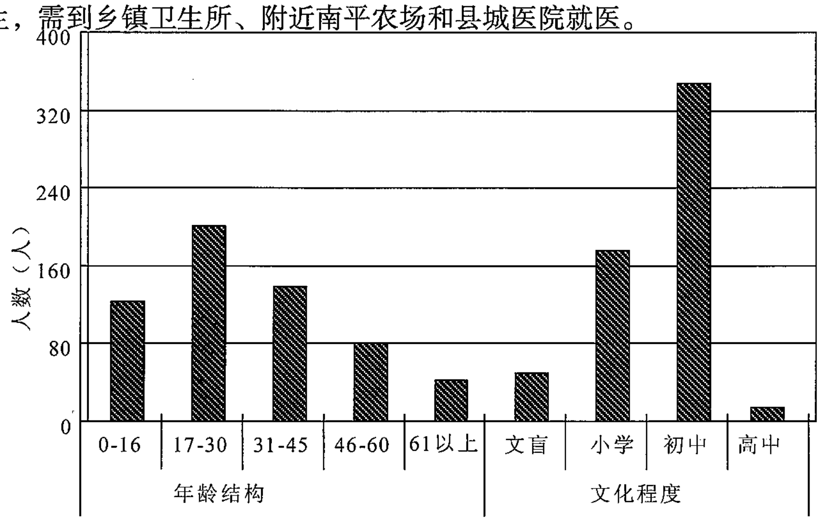

图8-2 大敢村人口年龄结构和文化程度分布

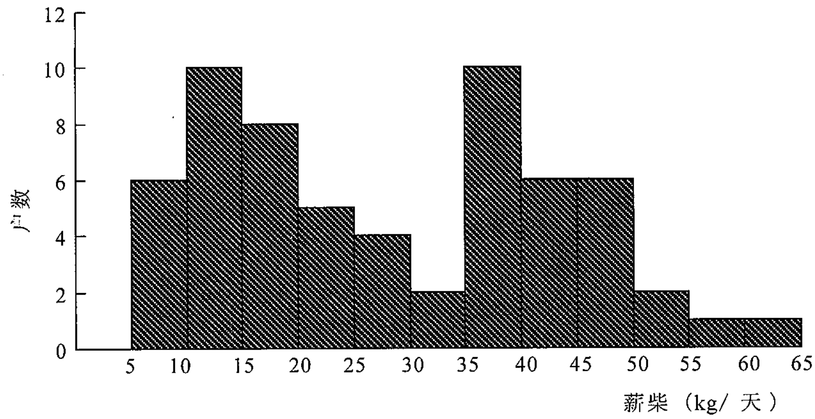

图 8-3　大敢村每日薪柴消耗户数分布

能源结构方面，薪柴是大敢村主要的能源来源，另有 5 户家庭以沼气为能源。据对 60 户家庭三天内平均每天的薪柴消耗量抽样调查显示，平均每户家庭每日消耗薪柴 28kg，人均消耗薪柴 5.5kg(图 8-3)，主要用于居民日常生活需要，如做饭、洗浴、煮食猪饲料等。调查发现，“靠山吃山”的观念在大敢村根深蒂固，使用薪柴成为社区村民的天然选择，并且这种能源利用较为粗放，居民普遍使用能源利用率较低的炉灶，电饭锅、电磁炉等没有得到普及，60 户家庭中只有 15 户家庭用电煮饭。薪柴主要来源于社区周边的天然林，以枯木或灌木为主。由于采集薪柴对天然林造成了一定的破坏，森林景观恢复措施的实施，将不可避免的影响这种天然的选择。因此应提倡煤、气、电等为薪柴的代用品，减少森林资源消耗，由于这些代用品的价格高于薪柴的价格，不利于推广，政府及有关部门应采取类似差额补助或扶贫政策加以解决，如补助沼气池修建费用等。

8.2.3　存在问题排序

大敢村存在的问题、原因和解决办法见表 8-2。需要特别说明的是，仅仅依靠森林景观恢复并不能在短期内解决所有问题，森林景观恢复的目的是恢复社区景观的生态完整性和提高居民福利，从长远来看，居民福利提高，社区存在的问题也就相应消失。对于大敢村来说，其 FLR 规划重点解决的问题是通过不同利益相关者之间的相互协商与合作，能够在短期内化解的困难，如表 8-2 列出的问题 1、2 和 5。至于其他问题，其根本原因是居民生活贫困，缺少资金，因此居民福利提高、社区收入增加后，这些问题都能得到解决。

道路差、交通不便是居民一致认为的、当前大敢村最急需解决的问

题，由于修路造价高、村民集资有限，所以最主要的解决办法是政府出资修路。作为大敢村近期最主要的基础设施建设，村级公路硬化是社区FLR规划的重要内容，拟借助当前拉动内需的国家政策倾斜，完成进村道路硬化，从而在改善交通条件的同时，实现资源优势向经济优势的转化，缓解对天然林的压力。灌溉用水不足是村民认为当前生活存在的第二大问题，并希望政府出资加高水塘、修建水沟，同时村民也意识到天然林对水塘的保护作用，这一问题反映在FLR规划中也属于基础设施建设，但是与森林恢复的关系更为密切，因此拟与县水利部门充分协商，将大敢村的水利设施建设列入水利部门近期工程规划。妇女入厕难、洗澡难的问题可以通过修建沼气池来解决，调查发现大敢村发展沼气池有很大优势，一是沼气原料充足，2009年全村共养猪682头，猪粪便可充分利用为沼气原料；二是政府补贴部分沼气池修建费用，群英乡已将大敢村的沼气池修建列入新农村建设，一口沼气池共需投资8000元，政府补助2000元，居民需投入6000元。修建沼气池既能解决居民能源问题和厕所问题，还能利用发酵后的沼渣还田解决橡胶、槟榔林缺肥问题。

表8-2 大敢村存在的问题排序

排序	存在问题	原因	解决办法
1	道路差、交通不便	无钱修路	(1)政府出资修路 (2)村民可以投工投劳 (3)5~6年后橡胶割胶后增加收入
2	灌溉用水不足	水塘的水少、无钱修水沟	(1)政府出资加高水塘 (2)村民集资修水沟 (3)种树保护水塘
3	槟榔、橡胶林缺肥	槟榔、橡胶太小，还不能收割，收入低、种植面积大，没钱买肥	(1)列入政府扶贫政策 (2)种木薯 (3)养猪、有机肥 (4)贷款买肥
4	缺住房	没钱盖房	(1)政府补助 (2)5~6年后橡胶割胶后增加收入 (3)外出打工攒钱

（续）

排序	存在问题	原因	解决办法
5	妇女入厕、洗澡难	缺厕所、卫生间	(1)政府补贴每户家庭修卫生间 (2)建沼气池 (3)村民集资修建几处公共卫生间
6	橡胶白粉病	缺农药、缺防治技术	(1)林业站派人指导 (2)政府发放农药 (3)技术培训

8.2.4　森林退化现状与原因

采用问题树方法对大敢村森林退化现状及原因进行分析。所谓问题树就是按照对事件的因果关系，将某一事件的原因逐级分解的方法。一般从出现的问题出发，往下追溯到引起该问题的最原始和最直接的原因。问题树可以帮助外来者和当地人一同发现和分析某一事件所产生的影响、资源和活动的流向，并表述起因、影响和联系，显示产生问题的原因之间的内在联系，发现其中关键的原因。通过村民大会、农户访谈等工具，对社区内天然林毁林、退化和破碎化的原因进行了分析，得出的问题树如图 8-4。大敢村现有退化原始林 42.06hm^2、次生林 47.55hm^2，只在社区东南部山顶位置有分布，而在 30 年前天然林分布广泛，几乎覆盖所有山顶，即使直到 1990 年退化原始林仍有 97.64hm^2，在 1990～2009 年期间退化原始林减少了 55.58hm^2，同时大面积连片分布的退化原始林已经很少，大多呈现破碎化分布。问题树表明造成天然林减少的主要原因是基本生活保障、林产品价格作用、扶贫支农政策和传统习俗引起的开发天然林，种植木薯、玉米等农作物，大面积发展橡胶、槟榔等人工林，以及开荒占地等。PRA 调查发现，大多数村民对于连片分布、质量较好的天然林都有一定认识，但是对于退化与次生森林的认识不足，尤其是对于次生林和部分退化林地的认识不足，认为这样的杂木林没有任何价值，因此部分村民在寻找新的人工林种植地时，首先选择此类杂木林作为开发对象。调查也发现，多数村民已经意识到天然林减少、森林退化引起的社会经济和环境问题，如水土流失加剧、受台风影响明显、水库缺水、缺乏盖房用的大径材等，并希望通过保护和造林实现天然林恢复。

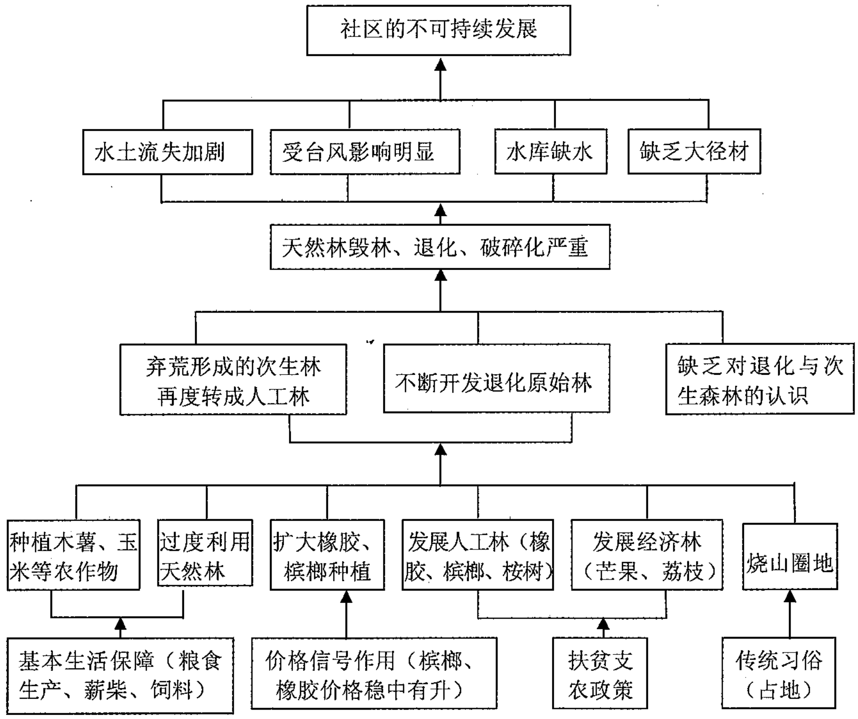

图 8-4　大敢村森林退化原因问题树

8.2.5　优先恢复立地及树种选择

村民大会上采用矩阵排序的方式得出优先恢复立地及其恢复措施和村民喜爱的树种见表 8-3、表 8-4。立地水平恢复措施应由社区居民实施，充分征求他们的意见，并将其体现在立地水平恢复方案中，有助于立地水平恢复措施的成功实施。值得注意的是，社区居民多从自身经济利益考虑恢复措施和造林树种，有些选择并不符合森林景观恢复的双重过滤器原则，甚至违背了恢复生态完整性的原则，如居民普遍认为马占

表 8-3　优先恢复立地及其恢复措施

优先恢复立地	措施	原因
道路两旁	种植城市绿化树种，椰树等	美化、遮太阳
水沟边	种本地树	保护水沟、水塘
平坦荒地	种橡胶，不种槟榔	提高收入，槟榔树已经足够
山顶荒地	种防风树(马占相思)、桉树	防风、卖钱
现有林地	保护	防风、保护山下的橡胶树

表 8-4　村民喜爱的树种排序

树种	好处	缺点	排序
橡胶	5 年后割胶，保留 50 年	白粉病	1
桉树	生长快、成活率高	5 年后砍伐，缺少水源	2
花梨(降香黄檀)	珍贵	生长慢	3
土沉香	珍贵、净化空气	生长慢	4
防风树	防台风、种于房屋四周	—	5

相思的防风效果最好，但是实地踏查发现，村民种于山顶用以防风的马占相思，大多在台风袭击下折断。此时，应及时协调不同恢复措施之间的冲突，尽量寻求经济效益与生态效益的折衷。

8.2.6　PRA 工具应用的技巧

在制定社区水平 FLR 规划时，不一定用到 PRA 的所有工具和方法，还有可能会根据实地情况丰富和发展 PRA 方法。

召开村民大会时，需要注意以下问题：第一，尽量使用当地语言，以平等身份表述，尽量使问题简单化，以保障人人都能接受，人人都能听懂(有些村民可能不好意思说他们听不懂)。如果有必要，可运用一些可视资料、游戏或故事向他们作解释。第二，首次村民大会村民参与程度较低，应以介绍为主，但是相互沟通、交流后，村民乐意提问、讨论、分享信息等，因此可以多种方式召开村民大会，合理运用 PRA 的工具(如参与式制图、农事季节历、绘制资源图等)。第三，注意引导会议向积极的方向发展，避免少数人主宰整个会议。此外，有些村民不愿意发言，即使他们被提问时也是如此。如果出现这种情况，应将村民分为几个小组进行分组专题讨论会。森林景观恢复工作小组应对讨论话题有所准备，预先了解他(她)们关心的问题，同时要注意他们的反应和情绪(激动、疲惫或厌烦)，并根据具体情况及时调整会议安排。第四，每次讨论、分析都要有结果、结论，有相应的讨论记录，并在下次大会上，将结果、结论反馈给村民，以便及时修正。第五，选择适当的时间和地点召开会议，会议时间不宜太长，1 ~2 个小时为宜。

示范区半结构访谈的经验表明：①访谈前应充分做好准备，包括半结构访谈的小组成员、设计访谈内容和选择访谈对象。大敢村为黎族自治村，森林景观恢复工作小组与当地居民存在语言交流的障碍，因此访谈小组应包括 1 名翻译，最好是请威信高的村干部或者学生担当翻译。②访谈的时间至关重要，应根据当地的日常工作和生活规律、季节农事活动、工作习惯、气候及地方习俗等确定访谈时间。③访谈应该是从家

庭结构(也就是家中人数、姓名、年龄、受教育程度等)、土地权属、作物种植面积、畜禽的种类和养殖数量这几方面开始。这样做，一方面是为了使农民消除疑虑增强其自信心，另一方面从谈话结果中可得到一些有价值的信息用来引导即将要涉及的次级主题。④为了得到合理且可靠的答案，森林景观恢复工作小组不应该向被访者暗示或许诺将来他或这个村子会得到什么好处。⑤应保证对被访者所回答问题的保密，不得随意暴露被访者的个人私事。⑥征得农民的同意再作笔记，并且不要用录音机来代替做笔记。每个人必须认真听取并详细记录所谈及的所有问题，包括其他人问的问题，这样做有助于检查笔记并可产生更好的问题，所记录下的不完整的答案可通过互相对照来填补，除此之外，还可避免重复。⑦访谈时间不宜过长，1 小时为宜，访谈结束时应向被访者致谢，并询问被访者有无问题问访问者。

采用矩阵排序能够充分体现社区村民的参与性，特别是像大敢村这样的边远山区、文化水平很低，用黎族村民能够理解的符号表达出矩阵排序的内容，既能激发村民的感性认识，又能达到调查的目的。

8.2.7 重视政府部门和乡土知识在 PRA 中的作用

重视政府部门在 PRA 中的作用。尽管参与式活动强调社区居民参与 FLR 规划、实施、监测与评估的整个循环，但事实上这些活动的实现都离不开政府的参与。各级政府部门，特别是林而言管理部门不仅介入 PRA 活动的组织与管理，而且直接影响着具体恢复活动的实施，是某些配套基础设施建设的主导力量。政府部门的参与有助于协调与处理社区与各部门的关系。当然，政府的参与应选用恰当的途径与方式，不能按照传统的自上而下、单向的、命令式或高姿态方式从事社区 PRA 的组织管理。而应当采取上下结合、相互沟通、互相学习与交流的方式，寻求优化的森林资源保护与社区发展途径。

充分利用当地居民的乡土知识(以及农民的传统知识等)。这是因为乡土知识是当地人使用的用于在特定的环境中谋生的知识系统(何丕坤等，2004)，具有如下特点：①乡土知识由于生长于当地的自然环境，所以具有很强的地方适应性。②乡土知识同当地的资源紧密结合，对乡土知识的充分认识有助于保护当地的乡土物种资源。与引进的技术相比，乡土知识基础上形成的技术更易于为当地人所掌握；乡土知识以当地的资源为基础，当地技术所用物资一般比较容易获得、供给稳定(如乡土树种等)，而且不需要使用现金支付，这也是避免风险的一种选择。③当地人民出于生计管理的需要，习惯于从各个整体角度出发解决问

题，而专家出于个人成就的需要大部分都“学有专攻”。专家在技术创新过程中往往专注于一个方面，比如产量和节能，而农民关注的是生计，必然在考虑问题的时候要从整体的角度出发。④贫困小农的乡土知识系统由于以生计为基本目标，更倾向于追求风险最小化而不是利润最大化。

8.3 小　结

本章结合社区水平森林景观恢复技术研究，以大敢村(FLR示范区)为例，研究了PRA方法在森林景观恢复中的应用。

(1)社区水平森林景观恢复是一个社区利益相关者共同分析森林景观问题和制定恢复规划，以实现恢复社区生态完整性和提高居民福利的过程。PRA方法为资料收集、利益相关者确定、格局分析、驱动力分析、优先恢复立地的选择以及立地水平恢复措施的实施，提供了一个主动而有效地途径。村民大会、实地踏查、参与式森林调查、半结构访谈和矩阵排序是应用于大敢村森林景观恢复的主要PRA工具。

(2)PRA的应用得到了大敢村与森林景观恢复相关的重要信息(如自然资源概况、社会经济概况、存在问题排序、森林退化现状与原因、优先恢复立地及树种选择等)，同时也是社区居民和其它利益相关者参与社区森林景观恢复活动的重要途径。

(3)大敢村当前存在道路差、灌溉用水不足、缺肥、缺住房、妇女入厕和洗澡难、橡胶白粉病等问题，其根本原因是居民生活贫困、缺少资金。仅仅依靠森林景观恢复并不能在短期内解决以上所有问题，规划重点解决的问题是通过不同利益相关者之间的相互协商与合作、能够在短期内化解的困难。但从长远来看，实施森林景观恢复，实现生态完整性恢复和居民福利提高的目标后，社区存在的问题也就相应消失。

(4)采用PRA方法，还应重视政府部门在PRA中的作用，充分利用当地居民的乡土知识(以及农民的传统知识等)。同时在应用中还要掌握各种技巧，如召开村民大会时，使用当地语言、避免少数人主宰会议、大会时间控制在1 ~2个小时内等，采用半结构访谈时，选择恰当的访谈时间、向被访者保证对其访谈内容进行保密、征得被访者同意后再作笔记、不随意承诺等。

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Study on Forest Landscape Restoration

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Preface

As the main body of terrestrial ecosystems, forest has a variety of ecological, economic and social benefits, playing an unique role in the maintenance of national ecological security, enrichment of forest products supplying, promotion of employment in rural and forest area, and improvement of people's livelihood. However, large areas of forest landscape have disappeared while forest degradation and fragmentation have also altered many forest landscapes because of over - harvesting and land use changes in the past century. The decline of forest productivity, forest habitat fragmentation, accelerated extinction of native species, environment degradation, rural poverty, social conflict and a series of problems have also emerged. "Forest Landscape Restoration (FLR)" provides a new approach to degraded forest landscape restoration, human well - being improvement, sustainable forest management and socioeconomic sustainable development. As a complementary framework to sustainable forest management, FLR combines a wide range of techniques and technologies, involving multi - disciplined knowledge of landscape ecology, forest ecology, stakeholder approach, public participation, adaptive management, and forest management.

With the increasing attention to FLR internationally, China has joined the Global Partnership on Forest Landscape Restoration (The Global Partnership on FLR) in March 2008. But China has lack a more complete and systematic study on the concept and approach of FLR, the international experience and lessons on FLR, as well as the system of FLR techniques and methods. Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this book constructed systematic approach to FLR from the view of regional - level and community - level (FLR at region level was the important complement to the FLR at community level), which is the first book to study the system of FLR theory and technology systematically in China. I believe the publication of the "Study on Forest Landscape Restoration" will be surely welcomed by research staff on forestry or other relevant fields, together with local foresters, and will make an important contribution to FLR implementation and regional socioeconomic sustainable development in China.

Academician of Chinese Academy of Science 

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Summary

Forest landscape restoration (FLR) is a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes. It provides a complementary framework to sustainable forest management and the ecosystem approach in landscapes where forest loss has caused a decline in the quality of ecosystem services. It doesn't aim to re-establish pristine forest, even if this were possible; rather, it aims to strengthen the resilience of landscapes and thereby keep future management options open. It also aims to support communities as they strive to increase and sustain the benefits they derive from the management of their land. As a vehicle for delivering on internationally agreed commitments on forests, biodiversity, climate change and desertification, FLR has got broad attention internationally. Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this book constructed the systematic approaches to FLR from the view of regional-level and community-level based on overview of study on FLR theory and techniques. Key techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies, and application of Participatory Rural Appraisal (PRA) method were put forward to provide the basis for restoration and sustainable management of degraded and secondary forests.

The systematic approach to FLR was constructed through field application of FLR in study area. Analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating are the contents and following steps to implement FLR. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in the contents. The "double filter", public participation and adaptive management are the principles that must be followed in the whole

process. These methods, principles and steps above constitute the systematic approach to FLR.

Three RS data (in 1991, 1999 and 2008) are the source of baseline information in landscape pattern analysis of Lingshui Li Autonomous County. Based on RS information extraction, participatory subcompartment division and inventory is the method to obtain the basic community-level data. In view of forest restoration and rehabilitation, system of forest landscape element types was set up, mainly including degraded primary forest, secondary forest, degraded forest land and plantation. In order to provide the basis for identification of priority sites and making FLR plan, landscape pattern and dynamics of study area were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The dominant forces responsible for changes on forest landscape were identified using transition probability matrix and the participatory approach. The results show that forestry policies and key programs are the dominant factors which cause the increase of forest quantity and quality during the period of 1991 to 2008 in Lingshui Li Autonomous County. Reducing rural poverty through development, livelihood development, village greening and farm-shelter, sand excavation, pond culture and tourism development are important factors in the changes on forest landscape in different areas of the county. Forest landscape dynamics during 1990 to 2009 in Dagan FLR demonstration area is the joint results caused by several driving forces, such as the basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices.

Based on the analysis of characteristics of degraded and secondary forests, the site-level restoration strategies were developed. Degraded primary forest has integrity community structure. Most of valuable trees in the sub-storey I in arbor storey have been used while there are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings. The basic restoration strategy for degraded primary forest can be perused protection and artificial measures promoting natural regeneration. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey. Protection and enrichment planting are the management strategies for secondary forest. Protective "decompression" is the main strategy for collective-owned secondary forest while enrichment planting combined with protection is the suitable strategy for individual-owned secondary forest. Species for enrichment planting should be valuable native trees, such as *Dalbergia odorifera*, *Hopea exalata*. The rehabilitation strategy for degraded forest land focuses primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Planting live green fence is one of the effective measures for protection of degraded and secondary forests.

The results of study on the application of PRA at the community level showed that the most important information related to FLR in Dagan FLR demonstration area could be got by PRA method and PRA was the effective approach to help community residents and other stakeholders to participate in FLR activities. PRA provided a proactive and effective approach for implementation of FLR and could embody the public participation of FLR theory.

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1 Introduction

As the main body of terrestrial ecosystems, forests not only provide material products and environmental services for human beings survival and development, but also play an irreplaceable role in the maintenance of biodiversity, improvement of ecological environment, maintaining the global carbon balance and supporting human lives. However, over-harvesting and land use changes that result in the disappearance of large areas of forest landscape, also result in the forest degradation or fragmentation in the past century. Globally, an estimated 40 – 50 percent of the original forest cover has disappeared, and of that which remains in the tropics, less than half is still found in large, contiguous tracts. Most of the rest exists only in the form of fragmented, modified or degraded woodlands and other areas too degraded to be even classified as forest (IUCN, 2005). At least 830 million ha of tropical forest are confined to fragmented blocks, of which perhaps 500 million ha are either degraded primary or secondary tropical forest and can be considered part of modified forest landscapes (ITTO and IUCN, 2005). Secondary forest resulted from degraded primary forest that were unable to regenerate and beyond the normal effects of natural processes. These forest areas have lost most of the forest attributes (structure, function, productivity, composition) (ITTO, 2002). Forest degradation and fragmentation are also seriously affected the life of forest-dependent people, especially the poor who obtain building materials, fuel, food and other necessities from the forest, because they have only limited agricultural land, and mainly rely on forests as social security , social and economic problems would emerge if there is no forest. In 2001, the World Conservation Union (IUCN), the World Wide Fund for Nature (WWF), the International Tropical Timber Organization (ITTO) and other non-governmental organizations coined the term "forest landscape restoration" (Veltheim T, 2005), which was defined as "a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes", to face the challenge of restoration forest products and services in degraded or modified forest landscapes. In order to implement the idea of forest landscape restoration to action, IUCN, WWF and the Forestry Commission of Great Britain launched the Global Partnership on Forest Landscape Restoration (The Global Partnership on FLR) in March 2003 in Rome, providing a shared worldwide experiences and mutual learning tool.

At present, China is on her way of building a moderately prosperous society in an all-round way and in the new development stage of accelerating the socialist modernization. The harmony between economic development and population, resources, environment, as well as sustainable development strategy of People in Harmony with Nature have entrusted an important position on forestry. Forestry is not only an important basic industry of national economy, but also one of public welfare utilities concerning ecological environment development. It shoulders the dual mission of optimizing the environment and promoting development, playing an irreplaceable role in achieving sustainable social and economic development. Forest resources are the basis for sustainable forestry development and in order to achieve sustainable forest development, it is necessary to manage forest sustainly.

Strictly speaking, except few primary forests in the southwest of China (southeastern Tibet), the northeast and the Tianshan Mountains, forest in other areas of China can be classified as degraded forest. Forest degradation would cause the decline of forest functionality, and are the root causes for other environmental degradation (Liu G H et al, 2000). If we want to successfully address some of the major challenges facing management and conservation of natural resources, including contributing to poverty reduction, biodiversity conservation and enhancing resilience to climate change, then just rely on large areas of continuous forest cover stretching uninterrupted forests is not enough. On the other hand, natural forest in China is mainly distributed in the northeast and southwest state forest region, the southern collective forestregion, as well as Tibet and the Northwest forests, are the livelihood and culture basis for forest-dependent communities (mainly minority residents) in remote mountainous areas that have poor infrastructure development. With strict protection of natural forest resources, the contradiction between forest protection (ecological construction) and local economic development (community life) has been increasingly prominent. Therefore, it is necessary to seek approaches to restore degraded and secondary forests and improve the welfare of community residents to promote the sustainable management of natural forests and the sustainable economic and social development.

FLR provides a complementary framework to sustainable forest management and the ecosystem approach in landscapes where forest loss has caused a decline in the quality of ecosystem services. As a vehicle for delivering internationally agreed commitments on forests, biodiversity, climate change and desertification, forest landscape restoration has drawn widely international concern.

Under the impetus of IUCN, WWF, ITTO and other international organizations, many countries and regions are actively engaged in the implementation and research of forest landscape restoration.

However, we still lack a complete and systematic study on the concept and approach of FLR, the international practical experience and lessons of FLR, as well as the systematic approach to FLR. Therefore, it is easy to copy the practice from other countries, or refuse to accept FLR for being unable to indentify the differences between FLR and forest restoration, ecosystem restoration or community forestry.

In fact, China has accumulated substantial experiences in forest rehabilitation, such as the Natural Forest Protection Program (NFPP), the Conversion of Cropland to Forest Program (CCFP) and other major forestry programs (Li W H, 2004). Studies have been conducted on participatory forestry, forest resources monitoring and evaluation, silviculture, analysis of forest landscape pattern, and ecological restoration etc., which are the theoretical basis of FLR or methods involved in FLR. China has joined the Global Partnership on Forest Landscape Restoration in 2008, taking FLR to the level of national decision-making. Therefore, it is a new task for us to study FLR from the perspectives of both theory and practice.

2 Previous works

2.1 Study of FLR implementation

The implementation of FLR at national level was started from the "Ngitili (woodland important to local livelihoods)" restoration in Shinyanga, northern Tanzania since 1985. By the year 2000, over 350,000 ha of Ngitili have been restored in the 833 villages of the region in a period of 15 years, human well-being has been significantly improved from aspects of per capita income and forest products output, etc (Barrow et al, 2002). As an example of forest landscape restoration, Shinyanga may not be a textbook case. It certainly predates the term FLR and has its origins in soil conservation rather than landscape restoration. However, it quickly evolved away from traditional forestry practice to the wider restoration of forest goods and services - and it illustrates perfectly the central aim of FLR to restore landscape integrity while also enhancing human well-being (Monela et al, 2005). At the same time, Kenya, Uganda, Vietnam, Laos, Cambodia, Thailand also began the reconstruction of degraded forest landscapes (Gilmour D A et al, 2000).

Under the impetus of IUCN, WWF, ITTO, FAO and other international organizations, many countries and regions are actively engaged in the implementation of forest landscape restoration, and many successful cases of FLR have been emerged(IUCN,2005a; Thomas P T, 2005). Working examples from 5 ecoregions supported by WWF are: protection and restoration of the floodplain forests of the Bulgarian Danube Islands, restoring panda landscapes in China, protecting and restoring habitat along the Kinabatangan River in Malaysia, increasing the extent and quality of Brazil's fragmented Atlantic forest, protecting and restoring the dry tropical forests in New Caledonia (Ecott T, 2002). Degraded hillsides in the Middle Hills of Nepal have been restored by natural regeneration under monoculture plantation (Lamb D, 2003). Ecological integrity and human well-being at a landscape scale have been enhanced in Indonesia. Meanwhile, central and western Finland, the

Nordic region, central Russia, Scotland have launched FLR programs (Veltheim T, 2005; IUCN, 2006).

Practice of FLR has been developed rapidly since the Petropolis Workshop on Implementation of FLR held in April, 2005 in Petrópolis, Brazil. Some successful examples of using FLR approach to restore important forest products and ecological services of degraded or deforested landscapes and thereby improve human well-beings in the field were listed in "the Petrópolis Challenge", including FLR works in Tanzania, United Kingdom, Brazil, China, India, Mali and so on. "Arborvitae", the IUCN/WWF Forest Conservation Newsletter, provided some cases worldwide, including Ngitili restoration in Tanzania, restoring a mangrove wetland in India, restoring ancient woodlands in England, restoring Cork Oak Landscapes in Portugal support by WWF, etc. (IUCN and WWF, 2005). Meanwhile, "Restoring Forest Landscapes: an introduction to the art and science of forest landscape restoration" published jointly by ITTO and IUCN in 2005 based on the "ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests" which were published by ITTO in collaboration with FAO, Intercooperation, IUCN and WWF International in 2002, has been compiled as a series of "essential reading" chapters on the key principles and techniques of FLR and will serve as a bridge between the policy-level guidance provided by the ITTO guidelines and the context-specific field guides. The main aim of Restoring Forest Landscapes is to help forest-restoration practitioners to understand FLR, appreciate its benefits and start to implement it (ITTO, 2005).

Some successful lessons for implementing FLR can be identified from the analysis of some examples in different areas: developing practical and comprehensive objectives, involving of local people in the decision - making process and subsequent implementation, placing local communities in the centre of attention, i. e. considered as the main actors, being promoted and supported by government, recognizing restoration not the substitute for the prevention of forest degradation and not full recovery of all functions of forest values, making the right choices between natural regeneration and human restoration, taking a landscape-level perspective into account in site-level management.

Experience has shown that successful forest landscape restoration starts from the ground up, with the people who live in the landscape and stakeholders directly affected by the management of the landscape. There is no blueprint for successful forest landscape restoration, since each situation will develop from local circumstances. Restoring forest landscapes is a tricky business. There are three common impediments to its implementation: determining the interests or preferences of the various stakeholders, identification of priority sites, incentives and compensation. The most important factor is to improve public participation (from on-the-ground practitioners to international organizations and policy processes concerned with forests), especially the participation of local inhabitants.

2.2 Global partnership on FLR

The joint strategy of WWF and IUCN entitled "Forests for Life" was one of the starting points of the initiative on FLR. This initiative set off and consolidated a global partnership of international organizations and governmental agencies. Before giving a conclusive definition of "Forest Landscape Restoration", the promoters of the Global Partnership focused on two complementary aspects: field experience and policy dialogue, including an important component of "partnership building". Moving from dialogue to action called for a dynamic approach to implementation that built a culture of success after the term of FLR was coined. This should involve linking inter-governmental initiatives with concrete actions at the local and regional level - explicitly linking policy with practice - and bringing key actors together to share constructive insights and identify opportunities. In response to this challenge, the Global Partnership on FLR was established and was formally launched in Rome in March 2003. Its continuing aim is to catalyze and reinforce a network of diverse examples of forest landscape restoration that deliver benefits to local communities and nature and contributes to the fulfillment of international commitments on forests (Dudley M, 2005).

Partners include the governments of United Kingdom, Kenya, Finland, the United States, Japan, El Salvador, Italy, Switzerland and South Africa, the Forestry Research Institute of Ghana, the Centre for International Forestry Research (CIFOR), IUCN, WWF, the UN Food and Agriculture Organization (FAO), the International Tropical Timber Organization (ITTO), the

Program on Forests (PROFOR), the UNEP - World Conservation Monitoring Centre (UNEP-WCMC), the Secretariat of the UN Forum on Forests (UNFF), the World Agroforestry Centre (ICRAF), the Secretariat of the Convention on Biological Diversity (CBD), the Alliance of Religions and Conservation (ARC), and CARE International. China has become one of the members of partners in 2008. Positive steps on forest landscape restoration are also being taken in many countries beyond the work of the partnership (IUCN and WWF, 2005).

More than 100 participants from 42 countries attended the "Workshop on Forest Landscape Restoration Implementation" held in Petrópolis, Brazil on April 4 - 8, 2005. The participants described FLR and highlighted its contribution to the Millennium Development Goals (MDGs) and to national development processes. The partnership encouraged new members to come on board and called for the restoration of forest landscapes to benefit people and nature and contribute to reversing the trends of forest loss and degradation. Workshops have been held in a wide range of countries including Brazil, China, Colombia, Pakistan, Thailand, Ghana, Vietnam, and in sub-regions or regions such as Mt. Elgon in Kenya/Uganda, the Mediterranean, Central and Northern Europe, West, East, Central and North Africa, South East Asia, Meso and South America (Veltheim T et al, 2005; IUCN, 2005; Barrow et al, 2002; Ecott T, 2002).

2.3 FLR in China

With the increasing attention to FLR internationally, China has also started the study on FLR. A workshop on Forest Landscape Restoration in China was held in Sichuan Province in 2004, which was the first seminar on FLR in China. On behalf of the State Forestry Administration, Jiang Zehui attended the international workshop on Forest Landscape Restoration in Brazil in April 2005 and made a presentation titled "Ecological landscape restoration of degraded land and degraded forest in China (Jiang Z H, 2005)". China joined the Global Partnership on Forest Landscape Restoration in March 2008. At present, the project which aimed at restoring panda habitat landscape in Minshan, Sichuan funded by the WWF has been successfully commpleted. ITTO project "Training on Demonstration, Application and Extension of ITTO Manual on Restoring Forest Landscapes in Tropics of China" and IUCN project "Forest Landscape Restoration and Community Livelihoods Improvement" are being implemented smoothly.

Forest landscape restoration has also received attention from scholars in China, such as the Jia Lesi wrote a brief introduction to the book "Forest Restoration in Landscapes: Beyond Planting Trees" published by WWF in" Restoring forest landscapes" (Jia L S, 2006). Lou Xinpan summed up the importance of implementation of forest landscape restoration (Zhang X H et al, 2007). Although studies on theory and methods of FLR in China are still at the stage of translation and introduction, a large number of studies on landscape ecology, restoration ecology, participatory forestry, monitoring and evaluation, etc. have been conducted in China (Zang R G, 1998; Peng, Z H, 1999; Guo J p et al, 2000; BAO W K, 2001; Ren H et al, 2002; Guo J p and Zhang Y X, 2002; Guo X M et al, 2002; He Z S, 2003; Li X Z et al, 2004), which providing a solid theoretical foundation and technical methods for FLR in China. On the face of decline of forest landscape ecological function and human well-beings caused by forest degradation, fragmentation and modification, it needs to integrate existing landscape ecology, forest restoration, community forestry and other research results through learning lessons and advanced techniques on FLR from other countries to guide the work of forest landscape restoration in China.

3 Brief introduction of study area

3.1 Brief introduction of Lingshui Li Autonomous County

Lingshui Li Autonomous County lies in the southeast of Hainan Island. The county located at 18° 22′–18° 47′ N and 109° 45′–110° 08′ E, connecting Sanya city in the south, adjoining with Qiongzhong county in the north, and its east border is Wanning county, west border is Baoting county. It is 196 km from the center of the county to the capital (Haikou City) of Hainan Province (See Figure 3.1). The total cover land area of the county is 1,128 km^2 and water area is 79 km^2.

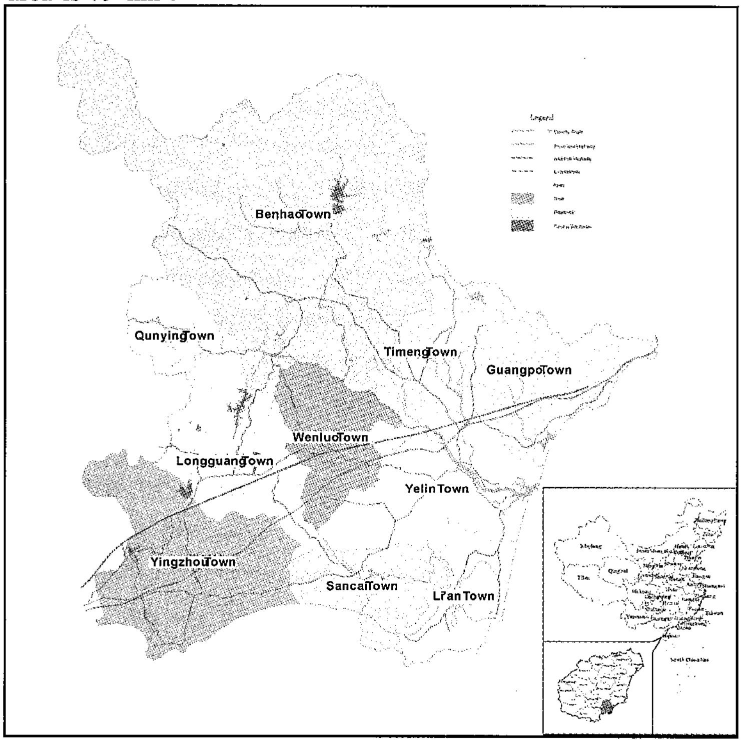

Figure 3.1 *Location and Administrative Division of Lingshui Li Autonomous County*

The climate of the county is classified as "tropical monsoon", where the annual average temperature is 24 ℃ and the annual rainfall is about 1,500 - 2,500 mm. The rain season and dry season are quite distinct. The rain season is from May to October while dry season lasts from November to next April. It is high in the northwest and low in the southeast of the terrain. The west is the mountain area, the middle part is the hilly area, and the southeast is the plain area. The peak is Diaoluoshan Mountain with an elevation of 1,499. 8m.

The soil of the county can be divided into 4 types, 14 subtypes, 28 soil genus. The Granite yellow soil is mainly distributed in mountains above the elevation of 750 m. The Granite laterite is mainly distributed in mountains with the elevation of 450 - 750 m. The soil type in the hills and tableland below 450 m is granite red soil.

Due to climate differentiation, the natural vegetation of Lingshui Li Autonomous County presents vertical distribution. Forest land and unused land are two land types of natural vegetation distribution, covers an area of 59,738 hm^2, accounting for 53. 4% of the total land area.

Natural vegetation types of the county are alpine coppice, mixed broadleaf-conifer forest, mixed evergreen-deciduous forest, secondary forest and planted forest. Alpine coppice is mainly distributed in Diaoluo mountain area above the elevation of 1,000 m. The growth of trees are limited and the height of trees is 5 - 8 m because of barren land and strong wind. Representative plants are *Polyspora axillaris*, *Castanopsis cuspidata*, etc. The mixed broadleaf-conifer forest is distributed in mountainside with altitude 600 - 1,000m. Representative trees are *Dacrydium pierrei Hickel*, *Hopea hainanensis*, *Homalium hainanense*, *Alseodaphne hainanensis*, etc. The mixed evergreen-deciduous forest is located in Niuling hills and suffered heavy human damage. The forest land which altitude is below 300m has converted into shrub land and secondary forest. The representative trees are *Vatica mangachapoi*, *Amoora dasyclada*, *Castanea henryi*. Secondary forest is mainly distributed in western mountains with elevation of 400 - 600m, including Daganling and Liaociling. Primary forest has been deforested and replaced by shrub and grassland. Planted forest is located in the southeast coastal beaches and barren sand hillsides. The native vegetation is thorn shrubs and cactus. The main tree species are *Casuarina equisetifolia*, *Eucalyptus emserta*, *Melia azedarach*, *Acacia confusa*, *Homalium hainanense*, *Cinnamomum Parthenoxylon*, *Dalbergia odorifera* and *Tectona grandis* after afforestation.

The county consists of 17 towns, with 114 administrative villages, 611 natural villages. The site has three state-owned institutions: Nanping farm under the province, Lingmen farm and Diaoluoshan forestry bureau. There are 16 minorities in the whole county, such as Li, Miao, Zhuang etc. In 2009 the total population is 364,000 and the Han accounted for 44. 8% while other minority accounted for 55. 2%. The main dialects are Chinese (Hainanese), Li and Miao language. Hainanese is the primary language. In 2009, the GDP of the county was 3. 81 billion RMB, of which the output value of the first, second and tertiary industries were 1. 91 billion RMB, 0. 75 billion RMB, 1. 15 billion RMB respectively. The ratio of industries was 50. 2: 19. 6: 30. 2.

3.2 Brief introduction of Dagan FLR demonstration area

Dagan FLR demonstration area is located in the Qunying town, that in northwest of Lingshui county. It is the area which main produce grains and economic crops in the central hills. The geographic coordinate is 18° 34′35″ N, 109° 51′05″ E, the size of the area is about 399. 48 ha, in which the size of cultivated land is 41. 14 ha (paddy field area is 26. 82 ha), including three villages, Dagan, Fenyou and Fenjie.

Landforms of the areas are mostly low mountains, hills, with the landform pattern of higher South to lower North, high in the East and West, and low in the middle with elevation of 30 – 340 m. Species diversity of the region is rich. The major soil type is brown-yellow soil. The site is suited for the growth of varied tropical cash crops because of sufficient rainfall, good light and temperature conditions and suitable climate. Moreover, the loam of strongly weathered granite is deep and contains much sand, also suitable for the growth of forests, parks and other woody plants. In the west of demonstration area there is a stream penetrating north-south section and running through Lingshui River, which provides irrigation water for agriculture and forestry.

Demonstration area has serious soil erosion and frequent meteorological disasters such as drought, typhoons. However, reduction of vegetation and land conversion due to desertification and human disturbance, such as slash and burn, management and investment, make the soil erosion even severe in rainy season. In addition, pond-deposit caused by soil erosion coupled with uneven seasonal rainfall also makes frequent drought in the area. For example, the original fields for autumn rice can not be used to grow spring rice due to lack of water. Rice can be grown in June and July even in rainy season. Typhoons also occur sometimes.

Demonstration area is a typical minority nationality habitant, belonging to the Li minority area, economic development in the area lagged behind the county average. The total number of families in demonstration area is 134 with a total population of 586 (Li nationality) in 2009. The annual per capita net income is about 110 US $. As to the total amount of land resources in the region, land rèsources is rich, but cultivated land is small, the average area of paddy fields is 0. 20 ha, which concentrated in the basin surrounded by hills and the original autumn fields can only plant as single-season field due to water shortages, a few is available for two seasons.

Economic income comes from forest and garden products. The main crops are rice, potato and maize, industrial crops are cassava, winter vegetables and fruits, and economic products are rubber, betel nut, papaya, mango and other tropical fruits, while the *eucalyptus* forest is also widely planted. Livestock and poultry are mainly local pigs, chickens, ducks and geese. Slash and burn is still a style of farming. The energy for domestic uses such as cooking, pig husbandry and bathing is also mainly from the trees in mountains.

In addition, transport in the demonstration area is impassable and the only one rural road to the county is in poor condition, which is unfavorable for the transportation of agricultural products, technology and information and. It will be surveyed and built under current policy-oriented of stimulating domestic demand.

4 Data collection and applied methodology

4.1 Data collection

Several remote sensing images of project area were collected (see Annex 3), including 3 images which completely coverd the county: the LANDSAT-TM images of Lingshui County on October 30, 1991, the LANDSAT-ETM images on December 31, 1999 and the SPOT2 images on May 15, 2008 (PAN and MULTI-BAND). High resolution images collected are aero photo in 1999 with resolution of 1m and SPOT5 image in 2006 with resolution of 5 m. Furthermore, land-use map of Lingshui County in 1997, revision of land use planning map of Lingshui County from 1996 to 2010 and land use planning map of Lingshui County from 2006 to 2020 were collected.

Two remote sensing images that covering Dagan FLR demonstration area were collected, which are aero photo of Dagan FLR demonstration area in 1999 and Worldview image of Dagan FLR demonstration area in December 9, 2008. The "11th Five-Year Plan" of Qunying Town and reports on basic conditions of the demonstration area were also collected. Field survey and drawing was conducted to get the edge of each patches with different uses, different ownerships, different conversion or development periods, so as to obtain forest landscape dynamics during the study period and the information of changes on rivers, roads and micro-topography.

4.2 Applied methodology

4.2.1 Remote sensing data processing

Selected clear ground points from 1∶10000 topographic maps as coordinates for image correction and then fused the images. Information extraction was carried out using methods of automatic classification in combination with visual interpretation. Different periods of landscape mosaic maps were obtained after post classification processing such as accuracy assessment and cluster analysis of small patches. Information extraction process was shown in Figure 4. 1.

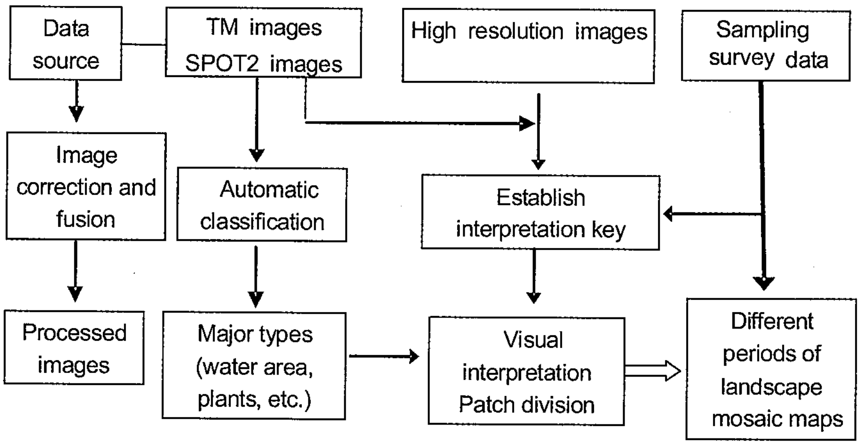

Figure 4.1 *The flow chart of remote sensing information extraction*

4.2.2 Landscape index method

Based on characteristics of the study area and research purposes, select representative landscape indices including the Class Area (CA), Area Percentage (PLAND), Patch Number (NP), Patch Density (PD), Mean Patch Size (MPS), Edge Density (ED), Mean Patch Shape Index (MSI), Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D). Use the tool "Patch analysis" which is an extension of ArcView GIS 3.3 (Chen W B et al, 2002; Bu R C et al, 2005; He P et al, 2009) to analyze the forest landscape patterns.

4.2.3 Landscape dynamics prediction model

There are many simulation models designed to study landscape dynamics, including Markov model, Logistic regression model and compartment theory, which are used to simulate the landscape dynamics under different disturbances. Markov model has been given more attention in prediction of forest landscape dynamics for its reasonable structure, strong practicability and high prediction accuracy. Based on this, Markov model was used in this book to analyze landscape dynamics from the point of FLR.

Landscape element types are the states in the Markov process during Landscape dynamics prediction. The ratio of area to the original area of landscape element types is called the transition probability. Supported by GIS tools, different periods of landscape mosaic maps were overlaid to get unchanged area of each types and the area converted to other types. Transition probability matrix was constructed using the ratio of area to the original area of landscape element types. Landscape dynamics was predicted using formulas 4.1 and 4.2.

$$S_{t+1} = P_{ij} \cdot S_t \qquad (4.1)$$

S_t, S_{t+1} are the states in stages t and (t + 1) respectively. P_{ij} is transition probability matrix, which can be shown by formulas 4.2.

$$P_{ij} = \begin{bmatrix} P_{11} \cdots P_{1n} \\ \vdots \\ P_{n1} \cdots P_{nn} \end{bmatrix} \qquad (4.2)$$

N is the number of landscape element types. P_{ij} is the probability of landscape element type (j) converted from landscape element type (i). Meanwhile, P_{ij} must be met two following conditions:

(1) $0 \leqslant P_{ij} \leqslant 1$;

(2) $\sum_{j=1}^{n} P_{ij} = 1 (i,j = 1,2,\cdots,n)$

4.2.4 Field inventory

In combination with participatory investigation, subcompartment division and subcompartment inventory were conducted in Dagan FLR demonstration area in Lingshui Li Autonomous County during the periods of November to December, 2008 and March to May, 2009 according to the "Technical regulations of forest management inventory" issued by the State Forestry Administration in 2003 and "Operation rules for Forest Resource Inventory in Hainan Province" issued by Hainan Provincial Forestry Bureau in 2008.

4.2.5 Method of characterization of degraded and secondary forest

4.2.5.1 Coenology method and forest measuration method

Community characteristics inventory was conducted using sample plot method to (Wang B S, 1996). Four communities of degraded primary forest and four communities of secondary forest in demonstration area were surveyed in March 2009. A strip plot with area of 720 m^2 composed of 20 quadrats (6 m × 6 m) for each community was set up. Trees with DBH ≥ 5 cm in communities of degraded primary forest were measured and trees with H ≥ 1.3 m in communities of secondary forest. Two typical sample circles were selected to investigate plants in shrub layer and herb layer. Important to value was calculated according to the concept proposed by J T Curtis and R P McIntosh. Forest measuration characteristics were inventoried combining community characteristics inventory (Meng X Y, 1996).

4.2.5.2 Species diversity

Species Richness, Species Diversity Index, Species Evenness and Ecological Dominance Index were chosen to measure species diversity. Species Richness (R) is the number of species that is the species richness communities (S). Use Shannon-Wiener index (SW) to express the Species Diversity Index, Shannon-Wiener evenness to express the Species Evenness (E), Simpson dominance index for Ecological Dominance (ED) (Wang B S et al, 1996). The formulas are as follows:

$$SW = \sum_{i=1}^{S} P_i \cdot \log_2 P_i = 3.3219(\lg N - \sum_{i=1}^{S} n_i \cdot \lg n_i / N) \quad (4.3)$$

$$E = SW/\log_2 S \quad (4.4)$$

$$ED = \sum_{i=1}^{S} n_i(n_i - 1)/(N(N-1)) \quad (4.5)$$

SW is Shannon-Wiener index, S is the number of species, n_i is the number of species i, N the total number of individuals of the community (plot), P_i is the percentage of the number of species i in the total number of species, E is Species Evenness, ED is Simpson Ecological Dominance.

4.2.6 PRA (Participatory Rural Appraisal)

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used in the study.

5 Systematic approaches to FLR

FLR takes a landscape-level view. It means that site-level restoration decisions needs to accommodate landscape-level objectives and take into account likely landscape-level impacts (WWF, 2004). The "Landscape" can be understood as one geographic area towards the horizon with conflicts, need to balance land-use trade-offs. Spatial entity covered by the region is changeable. From the theoretical point of view, the global, nation, sub-nation (state or province), city (district), county, town, village, and other administrative areas at all levels, as well as watersheds (natural areas) can be regarded as a Landscape. From the practical point of view, FLR mainly involves landscapes at two levels, one is the operational level and the other is the control level.

Landscape at operational level emphasizes the operability of forest landscape restoration measures and decision-making process of "bottom up". Village is the most appropriate scale and the community level is the most appropriate formulation. Although the community can refer to the "Earth Community", the community is usually understood as "a fixed geographical area where the members exercise social functions, create social norms matters based on living environment, which is the same level as village". Landscape at control level emphasizes the role of macro-control of FLR and the decision-making process of "top down". The region of "regional economic and social sustainable development" is the most appropriate scale and the region level is the most appropriate formulation. The county is the full grass-roots administrative unit and the county economy is the foundation of national economy. The county is the most basic spatial scale for regional economic and social sustainable development. Therefore, the FLR includes FLR initiatives both at region level and community level. The "community" refers to the villages while the "region" means the county or the unit above county.

Taking FLR planning process of Lingshui Li Autonomous County and planning and implementation process of FLR in Dagan demonstration area as a case, this book constructed the systematic approach to FLR according to Chinese conditions in terms of the stakeholder analysis, building FLR support, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating.

5.1 Framwork of FLR approaches

Analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating are the contents and following steps to implement FLR. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in FLR. The "double filter", public participation and adaptive management are the principles that must be followed in the whole process. These methods, principles and steps constitute the systematic approach to FLR (see Figure 5.1).

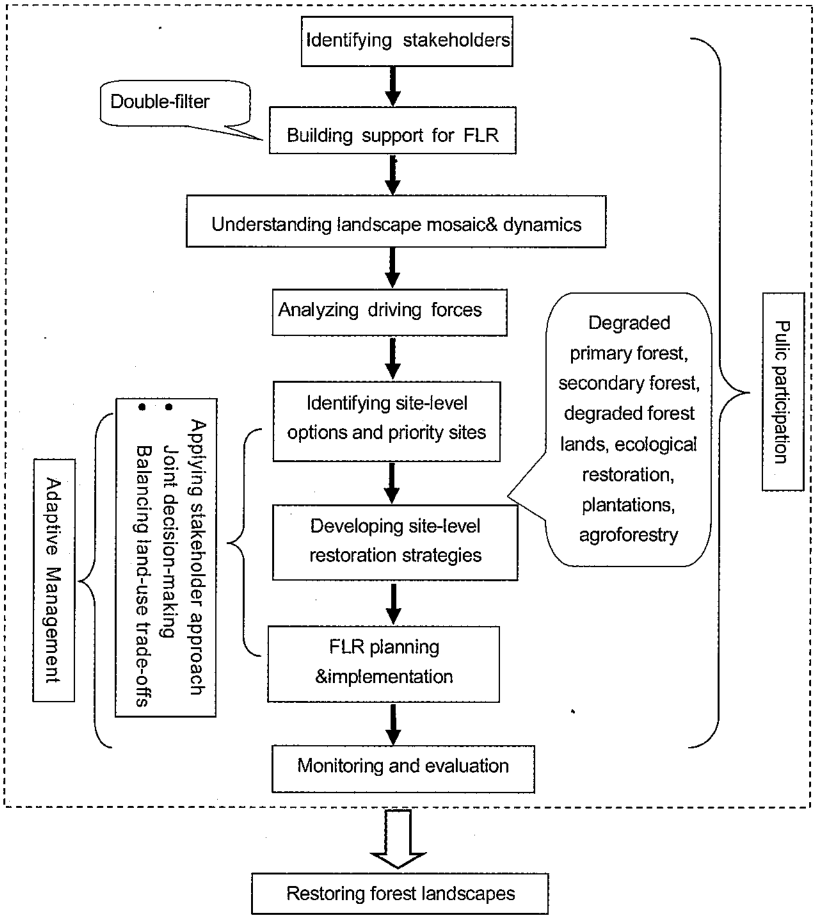

Figure 5.1 ***Framework chart of FLR approaches***

5.2 Stakeholder analysis

It is the first step to identify the key stakeholders in FLR implementation. A stakeholder is defined as an individual, a group of people or an organization that can directly or indirectly affect the FLR initiative in Lingshui Li Autonomous County or can be directly or indirectly affected by the FLR. Using common approaches, such as identification by the stakeholders themselves, by other stakeholders, by knowledgeable individuals or groups, by field-based staff of the FLR initiative and identification based on demography, stakeholder groups of FLR initiative in Lingshui Li Autonomous County were identified. They are Lingshui Forestry Bureau, Lingshui Agriculture Bureau, Lingshui land, Environment and Resource Bureau, Lingshui Tourism Bureau, Lingshui Water Bureau, Lingshui Marine and Fishery Bureau, Lingshui Ethnic and Religious Affairs Bureau, Lingshui Development and Reform Bureau, Lingshui Poverty Alleviation and Development Office, and three state-owned institutions: Nanping Farm under the province, Lingmen Farm and Diaoluoshan Forestry Bureau.

Local villagers, indigenous groups, forest communities, local forestry agency, project staff, government agencies at different levels, civil society organizations, education and research institutions, and donors are stakeholders in Dagan FLR demonstration area (see Table 5.1).

Table 5.1 ***Stakeholder analysis of Dagan demonstration area on FLR***

Stakeholders	Characteristics	Needs, interests	Potentials	Degree of participation
Primary stakeholders				
Local villagers, indigenous groups	Owners, derive income from forests, active group	Under poverty, lack of economic incentives and alternative economic source	Desire to receive Assistance, local knowledge, belief in institutions	Directly involved in FLR implementation, Primary project Beneficiary
Forest communities	Owners, depend on degraded and secondary production forest, active group	Base for community Development threatened, lack of economic incentives	Desire to receive assistance; local knowledge, belief in institutions	Directly involved in FLR implementation, Primary project Beneficiary
Local forestry agency	Responsible for sustainable forest management	Insufficient capacity for reducing deforestation and degradation	Experienced in forest inventory and working with villagers	Directly involved in FLR implementation

(continued)

Stakeholders	Characteristics	Needs, interests	Potentials	Degree of participation
Local government agencies	Responsible for making and implementing community development plans	Lack of information on FLR	Authority and influence in community, can implement FLR	Directly involved in FLR implementation
Secondary stakeholders				
Civil-society organizations	Actively involved in implementing and provide advice to rural development activities	Lack skills for advice on village development micro-planning	Experienced in working with villages	Can assist the project to implement relevant activities
Private sector	Owners of high-yield production plantation	Lack of information on FLR, needs to seek investment opportunities	Experienced in logging, investment capacity	Can assist the implementation FLR relevant activities
Tertiary stakeholders				
Education and research institutions	Have education and research missions	Lack means to finance collaboration	Competence in research, studies and surveys	Might collaborate in implementing relevant activities
Donors and finance institutions	Finance local development activities	Lack means to finance collaboration	Experience in implementing FLR	Might collaborate in FLR initiative

As forest-dependent people, local villagers, indigenous groups and forest communities in project area are concerned about and benefit from the FLR initiative. FLR will help them to reduce poverty, improve livelihoods through increased forest products and services. Local forestry agency that is responsible for management and protection of degraded and secondary forest are directly employed to conduct the fieldwork of the project. They will get experience on how to reduce deforestation and forest degradation. Government agencies are lack of information for policy decisions concerning FLR planning and reducing deforestation and forest degradation. The FLR initiative will help them to improve institutional implementation capacity for restoration and rehabilitation of secondary forests and degraded forest areas, avoid unplanned deforestation and all types of forest degradation, as well as improve the capacity for adaptation of tropical forests to negative effects brought about by climate change and human-induced impacts. Civil society organizations involved in implementing rural development activities will benefit from the improved capacity to participate in policy development and strengthen capability to support forest communities in improving their livelihoods and ecosystem services. For the private sectors who plan to convert degraded and secondary forest to high-yield production plantation will get information on newly developed policies for degraded and secondary forest and improve the capacity of implementing sustainable forest management (SFM). Donors and the international community will get valuable lessons and new knowledge on how to develop and implement financing mechanisms such as PES schemes and how existing support strategies can be enhanced to deliver the targeted global, national and local objectives.

5.3 Building support for FLR

Successful FLR requires supportive local and national policy frameworks and a strong constituency of local-level support for the restoration activities. Building support for FLR is to build the support of stakeholders for FLR initiatives. During the planning, the support of stakeholders for Lingshui Li Autonomous County can be built by a series of activities: data collection, stakeholder analysis, holding training courses on FLR to representatives of stakeholder groups, participatory interviews and setting up the steering team of FLR. Holding training courses on FLR is the most important means of building support among these activities. The content of training courses related to socio-economic losses caused by forest degradation, the concept and characteristics of FLR, and successful experiences of global FLR initiatives, etc. "ITTO/IUCN Manual on Forest Landscape Restoration "and" ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Forests" are the main training materials.

In addition, consultations and communications with stakeholders were conducted through radio, television and posters to raise public awareness and understanding of the contribution of FLR to poverty reduction, local economic growth, environmental security, and biodiversity conservation (Elliott S, 2000; Marghescu T, 2001; Kerr J, 2002).

5.4 Understanding the landscape mosaic

A landscape mosaic is made up of different components, pieced together to form an overall landscape-level "patchwork". The actual composition of the mosaic and the pattern in which the components are distributed will be unique to each landscape. Different landscape elements have different contribution to the objectives of FLR (Castillo-Campos et al., 2008). Landscape mosaic analysis involves data collection, forest landscape classification and landscape pattern analysis, and other contents and methods (see Chapter 6).

5.4.1 Landscape elements classification

According to relevant definitions of different forest and non-forest conditions, combining with the resolution of collected RS images and the classification of national land uses, landscape elements classification system of Lingshui County was established in the view of FLR. There are totally 13 landscape element types: primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* plantation, trees around villages, other plantation, other forest land, residential quarters land, garden plots, agricultural land and other land.

5.4.2 Data collection and processing

Data of Forest Management Inventory can be used directly. However, there are no such kind of data meeting the requirements for time or funds. Under this circumstance, remote sensing data are the best source for region-level FLR.

Forest Management Inventory of Lingshui Li Autonomous County was only carried out in 1994 and mapping data has been lost. So the landscape pattern analysis was based on RS data in this study. Community-level data has been obtained by participatory subcompartment division and inventory based on RS image information extraction to indentify the edge of each patch which has different ownerships, different landscape types or different management histories. Information of each patch has been collected by direct observation, such as topography, slope position, slope, use status, community structure, vegetation cover, growing condition of forest stand, by asking, such as the origin, use, ownership, management, investment, conversion or development time of landscape patches in different period, and by investigation, such as the number of trees, height of trees, diameter at breast height and so on. Meanwhile, the conversion or development history, the underlying drivers, land use in future were all collected. Maps of landscape mosaic in different periods were presented under the support of GIS tools.

Different types of landscape elements should be the basis for classifying the patch boundaries for analysis of landscape pattern while different ownerships and landscape element types should be the basis for classifying the patch boundaries for identifying site-level restoration strategies.

5.4.3 Analyzing landscape pattern

Landscape analysis needs some methods to describe the spatial pattern quantitatively, compare different landscapes, distinguish the landscape with special significance, and identify interrelation among landscape patterns, function and process (Guo L et al, 2009). Quantitative research methods of landscape pattern include landscape pattern indices for landscape element characteristics analysis, landscape pattern analysis model for overall analysis, and landscape simulation model for simulating landscape dynamics.

Landscape pattern analysis both at region level and at community level can use landscape indices to describe landscape mosaic. Select Class Area (CA), Area Percentage (PLAND), Patch Number (NP), Patch Density (PD), Average Patch Area (MPS), Edge Density (ED) and Mean Patch Shape Index (MSI) to describe the characteristics of the landscape elements while the area, total number of patches, Patch Density (PD), Mean Patch Area (MPS), Edge Density (ED), Mean Patch Shape Index (MSI), Landscape Diversity Index (SDI), the Evenness Index (SEI) and the Dominance Index (D) for description of the general landscape characteristics.

In addition, contribution of key areas of the landscape to an FLR initiative should be also evaluated (see Table 5.2). For example, the plantation can serve as a buffer zone around restored and protected areas, playing ecological and social functions.

Table 5.2 ***Contribution of key areas of the landscape to an FLR initiative***

Key areas of the landscape		Contribution to an FLR initiative
Forest areas	Intact natural forest (large areas)	These contain much of the conservation and development values of the initial forest landscape and are often the key building blocks for FLR initiatives. They generally need to be connected with restored and rehabilitated areas of the landscape to strengthen their contribution to FLR objectives
	Intact natural forest (small areas)	These provide important conservation and development values on-site that can be enhanced by expansion and connection to other key forest patches and areas to be restored and rehabilitated
	Plantations	These contain some conservation and development attributes that can be enhanced by management. They can also serve as useful buffers around degraded forests and protected areas
	Degraded forest or shrublands (large areas)	These can be key targets for restoration and rehabilitation and for connecting to other parts of the forest landscape
	Degraded forest or shrublands (small areas)	These can provide some conservation and development values that can be enhanced by restoration and rehabilitation and by connecting these areas to other key parts of the forest landscape
Non-forest areas	Farmland	Management of this land can be modified to contribute to FLR objectives
	Trees on farms	These can contribute to conservation and development outcomes, particularly if connected with intact forest patches
	Riverine (riparian) stips	These are important habitat types and building blocks for connectivity in the landscape. They may require restoration or rehabilitation to protect both on-site and downstream soil and water values
	Degraded area	These provide an opportunity for rehabilitation for on-site conservation and development benefits and for improved connectivity between natural forest patches
	Eroded areas, landslips	These require special treatment to protect both on-site and downstream values

5.5 Analyzing forest dynamics and driving forces

Forest Landscape Restoration aims to restore the overall structure and functionality of forest landscapes, what we want to manage and restore is the product of dynamic forces acting as direct or indirect causes for changes. Landscape dynamics presents the changes in spatial structure in different scales. It is essential to understand the landscape dynamics and address the forces responsible for landscape change before implement the FLR initiative.

5.5.1 Analyzing and predicting of forest dynamics

The overall landscape structure and dynamics were shown by analysis of landscape indices and RS images. Class Area (CA), Area Percentage (PLAND), Patch Number (NP) were selected to describe the changes in the structure of the landscape elements, Patch Density (PD) and Edge Density (ED) for changes on heterogeneity of landscape element types, and the area, total number of patches, Patch Density (PD), Edge Density (ED), Landscape Diversity Index (SDI), the Evenness Index (SEI) and the Dominance Index (D) for changes on overall landscape characteristics. Landscape dynamics at community level can be analysis from changes on both landscape element types (that is the composition of different landscape element types such as forest lands, agricultural lands or residential quarters) and individual landscape element (such as the conversion to agricultural lands from forest land). Markov Model can be used to predict landscape dynamics both at region level and at community level. Supported by GIS tools, different periods of landscape mosaic maps were overlaid to get unchanged area of each types and the area converted to other types. Transition probability matrix was constructed using the ratio of area to the original area of landscape element types.

5.5.2 Analyzing driving forces of landscape dynamics

The dominant forces responsible for changes on forest landscape both at region level and at community level can be identified using transition probability matrix and the participatory approach. The source of changes on each landscape element types can be identified by analyzing the transition probability matrix, for example, the decrease of area of degraded primary forest would be caused by the conversion from this type to secondary forest, but the driving forces for this conversion can not be obtained by transition probability matrix.

Therefore, the dominant forces responsible for changes on forest landscape both at region level and at community level should be identified by participatory methods, such as semi-structured interviews, matrix, brainstorming, etc. to communicate and discuss with stakeholders based on analysis of transition probability matrix, combing interview with inhabitants in different areas, field investigation and look up relevant documents, as well as make use of existing data on resources, environment and socio-economic, especially policies and regulations on forest use and environmental protection.

5.6 Identifying priority sites

One of the key features of FLR is that site-level decisions need to be made within a landscape context and indentifying priority sites needs to take both landscape-level and site-level perspective into account. We must first determine the residual, undisturbed forests, particularly those forests of high conservation value forests as a starting point, and then gradually carrying out the specific site-level interventions at the landscape level (Hobbs and Norton, 1996). The variety of ecological conditions and diversity of stakeholder views mean that it may not be possible to restore forest at all sites in a landscape. However, by strategically targeting areas for various kinds of reforestation, these interventions will collectively improve the key ecological processes (e. g. hydrological functions, nutrient cycling etc), restore biodiversity and thereby improve livelihoods across the landscape.

There are many applicable principles for identifying priority restoration sites, as follows: (1) According to provisions of Article XIV of "The People's Republic of China Soil and Water Conservation Law" and Article XXII of "The People's Republic of China Forest Law Enforcement Regulations," hills slope above 25° which have been cultivated for agricultural land should be gradually converted to grass and forest. (2) Remaining areas of undistrubed or well-managed natural forest (most are primary forest) should be protected; plantations established around residual forests are a good way of protecting these from further disturbances. (3) Degraded primary forest and secondary forest are prohibited to be converted to plantations, non-timber forests or agricultural lands, which can be restored through protection, natural regeneration and valuable native trees enrichment planting. (4) Forest linkages or corridors can be created between remaining natural forest areas. It is the best if these are structurally complex and species-rich, but even monoculture plantations can be useful, especially if natural regeneration produces an understory beneath the tree canopy. (5) Buffer areas along road and river banks within landscapes can be fostered by creating forest linkages or corridors. (6) According to provisions of Article III of "Provides on Construction and Protection of Coastal Shelterbelt in Hainan Province", coastal shelterbelt should be under restoration and protection. (7) According to provisions of Article XVI of

"The People's Republic of China Soil and Water Conservation Law", protection forests such as water conservation forest, soil and water conservation forest, wind-breaking and sand-fixing forest should only be allowed harvested in forms of tending and regeneration. (8) Habitats for special species, areas liable to rockfall, landslide and debris flow, as well as other sites of ecologically important features should be protected or restored.

Based on these principles, priority sites of FLR initiative in Lingshui Li Autonomous County were indentified (see Annex 1) after discussion and consultation with different stakeholders, including degraded primary forests, secondary forests, degraded forest land, agricultural land with slope above 25°, forest corridors connecting secondary forest island (plaque), shelter belt (green corridor) along the roadsides and river banks, water conservation forest around the reservoir and farmland shelterbelts. Priorities sites of FLR in Dagan FLR demonstration area include degraded primary forests, secondary forests, degraded forest land, agricultural land with slope above 25°, plantation connecting degraded primary forest and secondary forest (forest corridors along ridges), forest along the roadsides and river banks (see Annex 2). Forest landscape restoration planning is to arrange restoration interventions for priority sites from the perspectives of time and space perspective and to implement the planning relying on stakeholders.

5.7 Developing site-level restoration strategies

The purpose of FLR is not to return forest landscapes to their original "pristine" state, even if that were possible. Rather, it should be thought of as a forward-looking approach that can help strengthen the resilience of forest landscapes and keep future options open. It is important to understand that any individual application of this approach will be a flexible package of site-based techniques – from pure ecological restoration through blocks of plantations to planted on-farm trees – whose combined contribution will deliver significant landscape level benefits. The site-level techniques can include: the rehabilitation and active management of degraded primary forest, the active management of secondary forest growth, the restoration of primary forest-related functions in degraded forest lands, the promotion of natural regenerationin degraded lands and marginal agricultural sites, ecological restoration, plantations and planted forests and agroforestry and other configurations of on-farm trees. The specific activities of any FLR initiative could include one or more site-level techniques. Indeed, a fundamental characteristic of FLR is the use of combined technical approaches to solve problems, rather than relying on one particular type of intervention.

5.7.1 Analysis of characteristics of degraded and secondary forests

Analysis of characteristics of degraded primary forests in the view of forest management would contribute to develop site level restoration measures in the light of local conditions. Characteristics of degraded primary forests in Dagan FLR demonstration area were analyzed. The community was composed of arbor storey, shrub storey and grass storey. The arbor storey has high species diversity and the Shannon-Wiener index (SW) is 3.61 – 4.46. Dominant species in the inventoried communities are (1) *Garcinia oblongifolia* and *Hopea exalata*, (2) *Engelhardtia roxburghiana* and *Garcinia oblongifolia*, (3) *Amesidodendron chinense* and *Garcinia oblongifolia*, and (4) *Sarcosperma laurinum*, *Dalbergia hainanensis and Polyalthia laui* respectively. The stand average DBH, height, growing stock and density are 10.2 – 14.3cm, 8.50 – 13.39m, 142.51 – 199.44 m^3/ha and 2,321 – 3,545 N/ha respectively. The DHB distribution of each degraded primary forests showed the inverse J shape. Most of valuable trees in the sub-storey I in arbor storey have been harvested while there are still many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in each forest stand have rich species and valuable tree saplings and seedlings. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey.

5.7.2 Site-level restoration strategies

Protection and natural recovery of degraded primary forest

Degraded primary forests still retains the main characteristics of the original forest, such as species composition, soil structure and stand structure, and has capacity of natural regeneration, and has important function of ecological protection, so a basic management principle of forest restoration is to "decompress", that is degraded primary forests can be restored as managed primary forest, even converted to primary forest by protecting the site from further disturbance or stress factors such as deforestation, over harvest of timber and non-timber forest products, slash and burn, etc. and allowing natural colonization and succession processes to occur. This strategy is sometimes called "passive restoration". Another measure to promote the protection of degraded primary forest is to plant live fence. Planting *Acacia mangium*, *Eucalyptus* and other fast-growing species as live fence in the boundary among planted forest, degraded forest land and agricultural land can protect the degraded primary forest from further human disturbance.

Protection and enrichment planting of secondary forest

Secondary forest from clear-cutting of degraded primary forest still has valuable native tree species in arbor storey, rich species and valuable tree saplings and seedlings in shrub storey and grass storey. So this type of secondary forest should be taken the same forest restoration measures as that of degraded primary forest, protective "decompression", that is to achieve natural recovery under the use of existing saplings, seedlings by establishing live fence and avoiding human disturbances as much as possible.

Secondary forest regenerated through a natural process after more than 10 years' abandonment of alternative land uses still has commercial timber species, but lack of valuable native species. Protection and enrichment planting are the management strategies for this type of secondary forest, using existing tree seedlings and saplings for protective restoration, together with planting of valuable native species to restore forest communities with commercially valuable trees, such as *Dalbergia odorifera*, *Aquilaria sinensis*, etc., so as to improve ecological integrity and community benefits. The biggest conflict for this type of secondary forest is between protection and development of planted economic forest. Local villagers are the decision makers in solving this conflict, which means the secondary forest is facing human interventions of converting to other uses all the time. Therefore, forest owners should be consulted about specific restoration activities such as tree species selection. It is a principle to select acceptable native species to balance economic benefit and ecological services, that is to meet the "double filter" condition of FLR.

Rehabilitation of degraded forest land

The rehabilitation for degraded forest land has been focused primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Most of degraded forest lands are characterized as low soil fertility and poor soil structure, soil erosion and subjected to frequently human disturbance. In such situations, restoration activities are better focused on the recovery and maintenance of primary processes. Firstly, pioneer trees were selected as nurse crop, important silvicultural characteristics of species suitable for nurse crop include fast-growing, tolerant to drought and diseases, if necessary, exotic species can be selected. Then valuable native species are planted understory. The sites will be logged in a few years to increase the lighting needed by native species. In this way, both rehabilitation of degraded forest ecosystem and income of local villagers will be improved. Because the degraded forest land is waste land after development for other uses and the use right belongs to the villagers who developed first, the species selection and decision-making for restoration activities should give full consideration to the value orientation of the villagers and implemented by local villagers.

Restoration forest functions on agricultural land (Agroforestry) Farmland shelterbelt forest can be developed in centrally distributed agricultural land, so that on-farm trees can play an important part in improving the microclimate of farmland, sand-fixing, resisting natural disasters, and improving ecosystem connectivity, etc. as well as providing forest products to local communities. As to agricultural land in special ecological position, including in river banks, roadsides, around the reservoirs, in hill slopes above 25°, they were indentified as priority sites for restoration and would be converted to forest lands gradually through agroforestry. Because Agroforestry aims to balance the developments of agriculture, forestry and animal husbandry, rare and valuable native tree species were selected for planting and interplant crops and understory cash crops were grown in the first few years of planting to increase economic benefits.

5.8 Monitoring and evaluation

FLR initiatives face major technical, economic, social, cultural and institutional challenges. Monitoring and Evaluation (M&E) provides information of changes. M&E needs to be prepared during the initial planning phase of the restoration and based on a good understanding of the context of the FLR intervention. M&E is the basis and foundation of adaptive management in FLR. The core of M&E is to establish a set of indictors to evaluate the context and implementation of FLR and to find the problems existing in current restoration activities and identify future options. A set of FLR M&E indictors was established following three principles: scientific principles, objective principle and realistic principle, including process indictors and outcome indicators, totally 77 indicators (see Table 5.3). It should be noted that the indicator system is not fixed and could be identified based on specific circumstances of FLR implementation sites, and it can be adjusted and supplemented.

Table 5.3 ***Indicator system of Monitoring & Evaluation for FLR***

Factors		Indicators
Process indicators	1 *Stakeholder participation*	1.1 identification of the right stakeholders and target groups 1.2 competence and level of authority of participating stakeholders 1.3 stakeholders' roles in the FLR process 1.4 disadvantaged groups, such as the poor, with attention to gender equity 1.5 early stakeholder participation in FLR planning 1.6 participation in implementation and monitoring 1.7 leadership groups/individuals for community development
	2 *Stakeholder consultations*	2.1 quality of information shared and how widely it is shared 2.2 partnerships among stakeholders 2.3 coordination of stakeholders 2.4 institutionalization of consultations to discuss issues and solve problems
	3 *Service delivery*	3.1 stakeholder satisfaction 3.2 services obtained by stakeholders 3.3 level of access of stakeholders to the advisory and support services 3.4 compliance with the workplans and schedules 3.5 extent to which FLR objectives were achieved
	4 *Community needs' assessment and dissemination of results*	4.1 information and communication tools produced 4.2 sensitivity to needs of weak/disadvantaged groups 4.3 community satisfaction 4.4 level of community participatory of the FLR intervention 4.5 spreading path and extent of assessment results
	5 *Stakeholder capacity-building*	5.1 demonstration actions undertaken 5.2 implementation of activities associated with project objectives 5.3 mechanisms for conflict analysis and resolution 5.4 strength of local self-governing organizations 5.5 organizational capacity of women
	6 *Implementation*	6.1 coordination of key stakeholders 6.2 incentives for restoration actions 6.3 flexibility to adapt as lessons are learned

(continued)

	Factors	Indicators
Outcome indicators	7 *Strengthened capacity of responsible agency(ies) to support FLR activity*	7.1 fiscal capacity of responsible agency(ies) 7.2 capacity of full-time multidisciplinary staff 7.3 volume of certified production 7.4 level of institutional capacity to sustain the results
	8 *Integrated resource management*	8.1 approved management plans(forest production, protected areas, etc) 8.2 production diversification (timber and non-timber forest products, environmental services) 8.3 existence of land-use plans
	9 *Landscape patterns and forest products*	9.1 area and area proportion of forest landscape element types 9.2 levels of fragmentation of forest landscape element types 9.3 landscape diversity 9.4 conditions of degraded and secondary forest 9.5 types and yield of forest products 9.6 sustainable harvest of non-timber forest production 9.7 levels of resource use 9.8 diversity of resource users 9.9 existence of degraded forests restoration plans
	10 *Recovery of ecosystem integrity*	10.1 forest coverage 10.2 species diversity 10.3 structure of forests 10.4 areas under natural regeneration 10.5 planted areas 10.6 protection measures for wildlife 10.7 improvement of wildlife habitat 10.8 functions played by the restored forests 10.9 existence of corridors to link forest ecosystems 10.10 use of local knowledge for FLR 10.11 water yield in the watersheds 10.12 level of soil erosion 10.13 frequency of forest fires 10.14 carbon sequestration 10.15 pressure of human activities (domestic animal, crop production, etc)
	11 *Diversified sources of community income*	11.1 availability of forest resources 11.2 access to forest resources 11.3 provision of wood/fuelwood to communities 11.4 provision of fodder from plantations 11.5 number of jobs created 11.6 jobs which went to targeted groups (women, tribal/ethnic groups, youth, etc) 11.7 changes in income
	12 *Financial income*	12.1 costs versus benefits 12.2 contribution to local finance 12.3 economic income of locally processed productions

(continued)

Factors		Indicators
Outcome indicators	13 *Participatory M&E*	13. 1 monitoring tools 13. 2 sources of information on ecological and socioeconomic dimensions 13. 3 method of data collection 13. 4 implementin agencies of M&E 13. 5 levels of public participatory 13. 6 contribution to reporting 13. 7 lessons learned

6 Analyzing landscape pattern at region level

6.1 Landscape elements classification

Any individual application of FLR will be a flexible package of site-based techniques, whose combined contribution will deliver significant landscape-level benefits. Site-based techniques within the context of an FLR program mainly refer to site-level strategies and their associated silvicultural techniques for restoring degraded primary forest, managing secondary forest, rehabilitating degraded forest land or restoring forest functions on agricultural land.

According to relevant definitions of different forest and non-forest conditions, combining the resolution of collected RS images and the classification of national land uses, landscape elements classification system of Lingshui County was established in the view of FLR. There are totally 13 landscape element types: primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* plantation, trees around villages, other plantation, other forest land, residential quarters land, garden plots, agricultural land and other land, as outlined in Table 6. 1.

Table 6. 1 ***Landscape element system of Lingshui Li Autonomous County***

No.	Class	Description
1	Primary Forest	Forest which has never been subject to human disturbance, or has been so little affected by hunting, gathering and tree-cutting that its natural structure, functions and dynamics have not undergone any changes that exceed the elastic capacity of the ecosystem.
2	Degraded Primary Forest	Primary forest in which the initial cover has been adversely affected by the unsustainable harvesting of wood and/or non-wood forest products so that its structure, processes, functions and dynamics are altered beyond the short-term resilience of the ecosystem; that is, the capacity of these forests to fully recover from exploitation in the near to medium term has been compromised.
3	Secondary Forest	Woody vegetation regrowing on land that was largely cleared of its original forest cover (ie carried less than 10% of the original forest cover). Secondary forests commonly develop naturally on land abandoned after shifting cultivation, settled agriculture, pasture, or failed tree plantations.

(continued)

No.	Class	Description
4	DegradedForest Land	Former forest land severely damaged by the excessive harvesting of wood and/or non-wood forest products, poor management, repeated fire, grazing or other disturbances or land-uses that damage soil and vegetation to a degree that inhibits or severely delays the re-establishment of forest after abandonment.
5	RubberPlantation	Land with rubber trees.
6	Trees around Villages	Lands which are planted trees around the villages.
7	*Casuarina equisetifolia* Plantation	*Casuarina equisetifolia* is the main tree species of coast protection forest.
8	Other Plantation	Referring to eucalyptus planted forest .
9	Other Forest Land	Forest land not classified as above types.
10	Residential Quarters land	House sites used for daily life (including the independent courtyard).
11	Garden Plots	Mainly refers to the litchi, mango, betel nuts and other non-timber forest
12	Agricultural Land	Cropland, including paddy field and non-paddy cropland.
13	Other Land	Land not classified as to other type, such as rivers, reservoirs, lake and sandy lands.

6.2 Forest landscape pattern

The total area of forest landscape inLingshui Li Autonomous County was 108,611ha in 2008. There were 6,303 patches and the average patch area (MPS) was 17.23 ha. The patch shape index (MSI) was 86.82. Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D) were 1.86, 0.70 and 0.80 respectively (see Table 6.2).

Table 6.2 ***Overall Features of Forest landscape Patterns in Lingshui Li Autonomous County (in 2008)***

Index	Area (ha)	NP (n)	PD (n/100ha)	MPS (ha)	ED (m/ha)	MSI	SDI	SEI	D
Value	108611	6303	5.80	17.23	131.67	86.82	1.86	0.7	0.80

Features of forest landscape elements in 2008 were shown in Table 6.3. The area of Agricultural Land was 26,651ha with 829 patches, which was the largest landscape element type, accounting for 24.5% of the area of landscape. Agricultural Land was mainly distributed in plain areas and bottomland of hills. Followed by Secondary Forest, its area was 24,764 ha with 344 patches, accounting for 22.80% of total area, mainly in the northern middle hills region and the whole hilly area. The area of Garden Plots was 8,693 ha, 8.00% of total area. This landscape element type had wide distribution including northern middle hills region, the hilly region, central plain area and coastland. The area proportion of Rubber Plantation and Trees around Villages were 7.66% and 6.78% respectively, ranking sixth and seventh. Rubber Plantation was mainly in the western hills and upper reaches of Lingshui River while trees around villages were distributed around the residence. There were 1,574 patches of *Casuarina equisetifolia* Plantation and Other Plantation. *Casuarina equisetifolia* Plantation was mainly distributed in coastal areas for coast protection forest with the area of 452 ha. The area of Degraded Primary Forest was 6,837 ha, accounting for 6.29% of the total area of the landscape. Degraded Primary Forest was mainly in the northern mountains (Diaoluo mountain forest area) with low disturbance where were far away from human settlements. The area of

Table 6.3 ***Features ofForest landscape elements in Lingshui Li Autonomous County* (*in* 2008)**

Landscape type	CA(ha)	PLAND%	NP(n)	PD (n/100ha)	MPS (ha)	ED (m/ha)	MSI
PF	5153	4.74	11	0.21	468.43	38.39	2.31
DPF	6837	6.29	110	1.61	62.15	57.52	2.00
SF	24764	22.80	344	1.39	71.99	68.23	35.14
DFL	2358	2.17	766	32.48	3.08	341.38	1.82
RP	8324	7.66	58	0.70	143.51	104.87	19.42
TaV	7365	6.78	505	6.86	14.58	265.76	839.83
CeP	452	0.42	44	9.73	10.27	213.37	2.02
OP	7235	6.66	1530	21.15	4.73	250.81	2.26
OFL	176	0.16	13	7.40	13.51	161.56	1.91
RQL	4126	3.80	1202	29.13	3.43	293.26	2.33
GP	8693	8.00	301	3.46	28.88	144.09	10.95
AL	26651	24.54	829	3.11	32.15	110.58	3.60
OL	6478	5.96	590	9.11	10.98	158.43	83.24

Note: PF – Primary Forest, DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, RP – Rubber Plantation, TaV – Trees around Villages, CeP *Casuarina equisetifolia* Plantation, OP – Other Plantation, OFL – Other Forest Land, RQL – Residential Quarters Land, GP – Garden Plots, AL – Agricultural Land, OL – Other Land.

Other Land covering rivers, reservoirs, lake and sandy lands was 6478 ha, occupying 5.96% of the landscape. Primary Forest was continuously distributed in northern Diaoluo mountain forest area with high altitude and its area was 5,153 ha, accounting for 4.74% of the landscape. Residential Quarters Land was mainly in eastern and southern coastal areas, accounting for 3.80% of the landscape. The area of Degraded Forest Land was 2,358 ha with 766 patches, covering 2.17% of the landscape. Most degraded forest lands were waste land after development of natural forest and scattered around in the secondary forest. In addition, the area of Other Forest Land not included in above forest types was 176 ha, accounting for 0.16% of the total area of the landscape.

Forest landscape pattern shows regular zonal distribution with different hydrothermal condition. Lingshui Li Autonomous County is high in the northwest and low in the southeast from a macro point of view. The county can be classified into four geomorphological regions: northern mountainous region, western hills area, central plain terrain and southeast coastal terrace. This geomorphological pattern and the resulting hydrothermal condition formed the unique forest landscape pattern of Lingshui Li Autonomous County (see Annex 4). Primary forest, secondary forest and degraded forest land were the main landscape element types in northern mountainous region. Western hills area was dominated by rubber plantation and secondary forest. Agricultural land and garden plots were the main landscape element types in central plain terrain while agricultural land and residential quarters land were dominated in southeast coastal terrace. Forest landscape of Lingshui Li Autonomous County presented high Landscape diversity index (SDI) and landscape dominance index (D). There were big differences among the area and the number of different landscape element patches. The area of both agricultural land and secondary forest was 51,415 ha; accounting for 47.34% of the landscape, thereby these two types could be regarded as the dominant landscape element types of the Lingshui County. Primary forest, degraded primary forest or rubber plantation in the landscape occupied a smaller proportion, but they all presented large patch size and centralized distribution. Moreover, degraded forest land had low patch connectivity and high fragmentation because of repeated human disturbance and the division of agricultural land and rubber plantation. Lingshui Li Autonomous County as a whole was a heterogeneous forest landscape in which forest lands as the matrix were intertwined by agricultural land and other land which had smaller patches, residential quarters land and garden plots were scattered among the matrix.

6.3 Forest landscape dynamics

6.3.1 Change on general features of landscape

General features of Forest landscape in Lingshui Li Autonomous County in different periods (1991, 1999 and 2008) were analyzed (see Table 6.4). The results showed that the number of landscape patches increased by 5340 and patch density increased to 6.72/100 hm^2 from 1.81/100 ha during 1991 – 1999 while the number of landscape patches reduced by 898, patch density decreased correspondingly from 1999 to 2008. Meanwhile, both landscape diversity index (SDI) and landscape evenness index (SEI) has increased, but landscape dominance index (D) has decreased during the period of 1991 – 2008. The area proportions of forest land accounting for the landscape in different periods (1991, 1999 and 2008) were 61.02%, 53.65% and 50.91% respectively, which showed that forest land has decreased gradually from 1991 – 2008 caused by the land use conversion from forest land to garden plots and residential quarters land.

Table 6.4 *Changes on general features of Lingshui Li Autonomous County Forest landscape*

Period (year)	Area (ha)	NP(n)	PD ($n/100hm^2$)	ED (m/hm^2)	SDI	SEI	D	Forest Land	
								Area (ha)	%
1991	108611	1961	1.81	74.13	1.16	0.45	1.42	66279	61.02
1999	108611	7301	6.72	131.99	1.55	0.59	1.08	58268	53.65
2008	108611	6303	5.80	131.67	1.86	0.70	0.80	55298	50.91

Changes of landscape indices showed that the number of landscape patches has increased significantly and each patch has become regular caused by the interdivision among different landscape element types ofLingshui Li Autonomous County from 1991 to 2008, which resulted in the landscape fragmentation become more and more evident (see Annex 4).

6.3.2 Change on landscape element types

Area of each landscape element type except primary forest has changed from 1991 to 2008 in Lingshui Li Autonomous County. The total landscape area of Lingshui Li Autonomous County was 108,611ha. The area of each landscape element type has changed except primary forest with the increase of areas of garden plots, trees around villages, residential quarters land, other plantation and the decrease of areas of secondary forest, degraded primary forest, agricultural land, *casuarina equisetifolia* plantation (see Table 6.5 and Figure 6.1). Summarily, the proportion of natural forest (including primary forest, degraded primary forest and secondary forest) was going down constantly (45.15% in 1991, 37.81% in 1999 and 33.83 % in 2008) and that of plantation forest(garden plots, rubber plantation, trees around villages, *casuarina equisetifolia* plantation and other plantation) was on the contrary (17.84% in 1991, 21.25% in 1999 and 29.52% in 2008).

Table 6.5 ***Changes on areas of different landscape element types ofLingshui Li Autonomous County***

Landscape type	CA(ha)			PLAND%			changes of area %		
	1991	1999	2008	1991	1999	2008	1991-1999	1999-2008	1991-2008
PF	5153	5153	5153	4.74	4.74	4.74	0.00	0.00	0.00
DPF	9882	8124	6837	9.10	7.48	6.29	-17.79	-15.84	-30.82
SF	34004	27790	24764	31.31	25.59	22.80	-18.28	-10.89	-27.17
DFL	954	1859	2358	0.88	1.71	2.17	94.95	26.87	147.34
RP	8200	9473	8324	7.55	8.72	7.66	15.52	-12.13	1.51
TaV	2283	7125	7365	2.10	6.56	6.78	212.14	3.37	222.65
CeP	1846	463	452	1.70	0.43	0.42	-74.91	-2.39	-75.51
OP	5505	4211	7235	5.07	3.88	6.66	-23.50	71.80	31.43
OFL	735	1196	176	0.68	1.10	0.16	62.65	-85.31	-76.11
RQL	2442	3057	4126	2.25	2.81	3.80	25.20	34.98	69.00
GP	1553	1798	8693	1.43	1.66	8.00	15.74	383.60	459.74
AL	29614	31365	26651	27.27	28.88	24.54	5.91	-15.03	-10.01
OL	6441	6999	6478	5.93	6.44	5.96	8.66	-7.45	0.57
Total	108611	108611	108611	100	100	100	—	—	—

Note: PF – Primary Forest, DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – Degraded-Forest Land, RP – Rubber Plantation, TaV – Trees around Villages, CeP *Casuarina equisetifolia* Plantation, OP – Other Plantation, OFL – Other Forest Land, RQL – Residential Quarters Land, GP – Garden Plots, AL – Agricultural Land, OL – Other Land.

According to the area change of single landscape element type, primary forest area has been kept stable. Secondary forest was the landscape element type with biggest changes on area, which changed from 34,004 ha in 1991 to 24,764 ha in 2008 and its proportion has decreased by 2.81%. Followed by

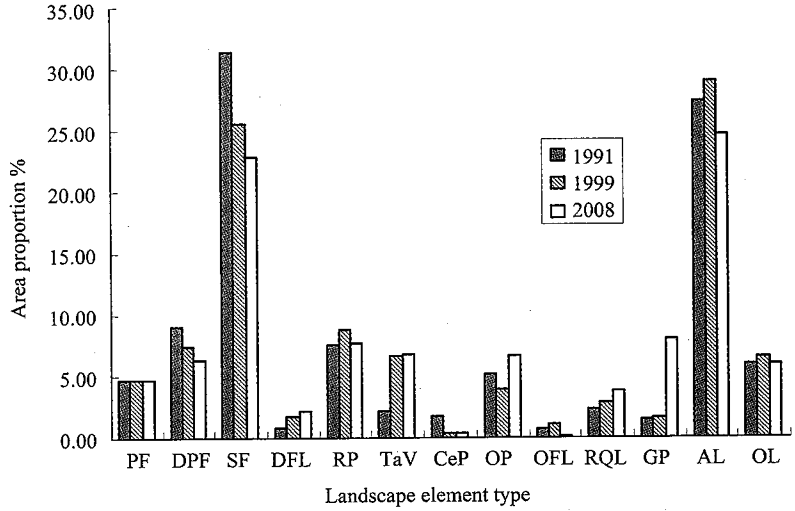

Figure 6. 1 ***Area proportions of different landscape element types of Lingshui Li Autonomous County***

PF – Primary Forest, DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – Degraded Forest Land, RP – Rubber Plantation, TaV – Trees around Villages, CeP – *Casuarina equisetifolia* Plantation, OP – Other Plantation, OFL – Other Forestry Land, RQL – Residential quarters land, GP – Garden plots, AL – Agricultural Land, OL – Other Land.

the degraded primary forest, the area has decreased by 3,045 ha and the proportion has reduced by 2.81%. Garden Plots was the landscape element type with the largest area increase, from 1,553 ha to 8,693 ha and area percentage has increased by 6.57%. Followed by trees around villages, the area has increased by 5,083 ha.

From the changes on area of landscape types in different periods, Garden Plots is the type with the biggest area changes, the area has constantly increased from 1991 to 2008 and the area in 2008 was 4.6 times of that in 1991, but the increase mainly occurred during the period of 1999 –2008. The area of Trees around Villages in 2008 was 2.23 times as much as that in 1991 and this change mainly happened in 1999 to 2008. The amplitude of variation of degraded forest land was 174.34%, which were 94.45% in 1991 to 1999 and 26.87% in 1999 to 2008 respectively. The area of Residential Quarters Land has also constantly increased, but amplitude of variation in 1999 to 2008 was bigger than that in 1991 to 1999. The area of Secondary Forest, Degraded Primary Forest and *Casuarina equisetifolia* Plantation has constantly decreased from 1991 to 2008 and mainly happened in the period of 1991 to 1999. Among those forest landscape types, the area of secondary forest and *Casuarina equisetifolia* Plantation changed significantly in two periods with decreasing area in 1991 to 1999 obviously more than that in 1999 to 2008. The fact that the area of secondary forest and degraded forest has reduced shown that the area of natural forest had a decreasing trend from 1991 to 2008. Changes on areas of Rubber Plantation and Other Lands increased first and then followed by decrease, but both types have increased due to the increased area in the previous period larger than the decreased area in the latter period.

By comparing Patch Density (PD) and Edge Density (ED) of various landscape feature types of Lingshui Li Autonomous County in 1991, 1999 and 2008 respectively, the heterogeneity change of landscape elements was analyzed (see Table 6.6).

Table 6.6 ***Changes on PD and ED of different landscape element types of Lingshui Li Autonomous County***

Landscape type	PD(n/100ha)			ED(m/ha)		
	1991	1999	2008	1991	1999	2008
PF	0.21	0.21	0.21	38.39	38.39	38.39
DPF	0.30	1.01	1.61	36.64	49.58	57.52
SF	0.30	0.75	1.39	38.91	52.67	68.23
DFL	8.39	33.84	32.48	141.70	285.40	341.38
RP	0.20	1.11	0.70	54.46	109.55	104.87
TaV	6.40	24.48	6.86	180.80	327.09	265.76
CaP	3.47	13.17	9.73	127.66	227.69	213.37
OP	2.14	35.64	21.15	119.61	293.79	250.81
OFL	2.86	2.84	7.40	150.68	165.34	161.56
RQL	21.34	29.90	29.13	200.27	270.10	293.26
GP	8.63	7.34	3.46	168.04	191.55	144.09
AL	1.90	3.86	3.11	82.31	133.72	110.58
OL	2.42	9.54	9.11	152.43	209.36	158.43

Note: PF – Primary Forest, DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, RP – Rubber Plantation, TaV – Trees around Villages, CeP *Casuarina equisetifolia* Plantation, OP – Other Plantation, OFL – Other Forest Land, RQL – Residential Quarters Land, GP – Garden Plots, AL – Agricultural Land, OL – Other Land.

In 1991, Residential Quarters Land had the biggest PD(21.34 /100 ha) and ED (200. 27m/ ha) with high fragmentation for the scatter composition pattern. The patch density index of Rubber Plantation was the smallest, 0. 20/100 ha, which showed that the cultivation area of Rubber Plantation was smaller in 1991 and concentrated in state-owned or collective-owned farms. The PD of Garden Plots, Degraded Forest Land, Trees Around villages were 8. 63 /100 ha, 8. 39 /100 ha and 6. 40 /100 ha respectively. These types showed higher degree of fragmentation for mosaic distribution among the types of other landscape elements caused by frequent human disturbances. Both Primary Forest and Secondary Forest had smaller PD and ED with more regular shape of patches because they had been protected and had concentrated distributions.

The rank of patch density index of different landscape element types in 1999 was similar to that in 1991. Patch density (PD) of other types had increased except Primary Forest and Garden Plots. The sequence of patch density index of different landscape element types in 1999 was similar to that in 1991. Patch density (PD) of other types had increased except Primary Forest and Garden Plots. The PD of Other Plantation had increased from 2. 14/100 ha to 35. 64/100 ha while that of Degraded Forest Land had increased from 8. 39/100 ha to 33. 84/100 ha. during the period of 1991 – 1999, showing that impact of human activities on Other Plantation and Degraded Forest Land had enhanced which resulted in further fragmentation of the two types. Trees around Villages was the type with the biggest edge density in 1999 and its patch density also varied obviously. Patch density indices of Degraded Primary Forest and secondary forest had increased as well as the area had deceased. This showed that impact on the two types by human activities had become bigger, the patch shape tended to be more complex and thereby they become more fragmented.

The patch density indices of Degraded Primary Forest, Secondary Forest had constantly increased from 1991 to 2008, which showed that the two types had become more and more fragmented. Except Primary Forest, the patch density of other types had increased first and then decreased during this period with different amplitude of changes, reflecting that the impacts on study area of human disturbances had first increased and then reduced. According to the changes on edge density of different landscape element types, primary forest had been kept stable in edge density, patch shapes of Degraded Primary Forest, Secondary Forest, Degraded Forest Land, Rubber Plantation and Residential Quarters Land became more and more irregular, and other types had become more squared during 1999 to 2008.

6.3.3 Prediction of forest landscape dynamics

Understanding the forest landscape dynamics is a major factor for successful implementation of FLR initiative since it is a process that will take at least 10 years, often much longer, facing major technical, economic, social, cultural and institutional challenges. Using Markov models, transition probability matrix among different landscape element types from 1999 to 2008 (see Table 6.7) was constructed to predict and analyze the forest landscape dynamics of Lingshui Li Autonomous County.

Table 6.7 ***Landscape class transition area of Lingshui Li Autonomous County form* 1999 *to* 2008**

1999	2008													1999
	PF	DPF	SF	DFL	RP	TaV	CeP	OP	OFL	RQL	GP	AL	OL	
PF	4.74	-	-	-	-	-	-	-	-	-	-	-	-	4.74
DPF	-	6.29	0.85	0.09	-	-	-	-	-	-	0.21	-	0.03	7.48
SF	-	-	21.95	0.93	0.31	0.18	-	0.90	-	0.04	0.66	0.50	0.11	25.59
DFL	-	-	-	0.16	0.23	0.03	0.01	0.97	-	0.01	0.17	0.08	0.04	1.71
RP	-	-	-	0.42	5.50	0.21	-	0.65	0.04	0.07	1.11	0.61	0.11	8.72
TaV	-	-	-	0.02	0.04	2.60	0.02	0.45	0.01	0.72	0.71	1.75	0.23	6.56
CeP	-	-	-	-	-	0.01	0.05	-	-	0.02	-	0.23	0.12	0.43
OP	-	-	-	0.12	0.32	0.48	0.06	0.92	0.04	0.14	0.62	0.89	0.29	3.88
OFL	-	-	-	-	0.07	0.05	-	0.08	0.02	0.03	0.28	0.56	0.01	1.10
RQL	-	-	-	0.03	0.07	0.54	0.01	0.09	-	1.75	0.09	0.20	0.04	2.81
GP	-	-	-	0.00	0.14	0.15	-	0.10	-	0.03	0.50	0.72	0.02	1.66
AL	-	-	-	0.32	0.81	2.32	0.08	1.91	0.05	0.86	3.22	17.83	1.47	28.88
OL	-	-	-	0.07	0.17	0.20	0.20	0.59	0.01	0.12	0.43	1.16	3.49	6.44
2008	4.74	6.29	22.80	2.17	7.66	6.78	0.42	6.66	0.16	3.80	8.00	24.54	5.96	100.00

Note: PF - Primary Forest, DPF - Degraded Primary Forest, SF - Secondary Forest, DFL - DegradedForest Land, RP - Rubber Plantation, TaV - Trees around Villages, CeP *Casuarina equisetifolia* Plantation, OP - Other Plantation, OFL - Other Forest Land, RQL - Residential Quarters Land, GP - Garden Plots, AL - Agricultural Land, OL - Other Land.

The results (see Table 6.8 and Figure 6.2) showed that forest and other natural landscape would reduce gradually while semi-natural landscapes such as agricultural land and human-induced landscape like residential quarters land would increase. This would result in degradation of landscape pattern towards poor ecological environment if Lingshui Li Autonomous County maintains the development trend of 1999 – 2008 in the next decades. The area proportions of agricultural land and residential quarters land would increase to 32.65%, 7.06% respectively while that of primary forest and secondary forest would reduce to 1.33% and 7.49% respectively by 2089. Obvious changes would occur in these four types. Other types including Trees around Villages, *Casuarina equisetifolia* Plantation, Other Plantation, Garden Plots and Other Forest Land would increase slowly. Rubber Plantation and Other Land would decrease and then climb up but in small fluctuation. Overall, this landscape dynamics would not be consistent with socio-economic development of the county, especially the sharp reduction of degraded primary forest, secondary forest and other natural forest together with the unlimited expansion of agricultural land, residential quarters land. Therefore, appropriate intervention should be undertaken on current landscape pattern to improve the positive direction of land use.

Table 6.8 ***Status and forecast of the occupation rate by each stage of landscape class types inLingshui Li Autonomous County***

Landscape type	Occupation rate(%)									
	2008	2017	2026	2035	2044	2053	2062	2071	2080	2089
PF	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74
DPF	6.29	5.30	4.46	3.75	3.16	2.66	2.24	1.88	1.58	1.33
SF	22.80	20.28	18.00	15.95	14.11	12.46	10.99	9.68	8.52	7.49
DFL	2.17	2.09	2.01	1.95	1.89	1.84	1.79	1.75	1.71	1.68
RP	7.66	7.60	7.73	7.88	8.02	8.15	8.28	8.38	8.48	8.57
TaV	6.78	7.55	8.20	8.72	9.13	9.49	9.79	10.05	10.28	10.48
CeP	0.42	0.43	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52
OP	6.66	7.43	7.63	7.73	7.81	7.88	7.94	8.00	8.05	8.09
OFL	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
RQL	3.80	4.46	5.01	5.46	5.85	6.17	6.44	6.68	6.88	7.06
GP	8.00	9.46	10.03	10.37	10.63	10.86	11.06	11.23	11.39	11.52
AL	24.54	24.72	25.82	26.97	28.02	28.94	29.75	30.47	31.10	31.65
OL	5.96	5.76	5.76	5.86	6.00	6.15	6.30	6.44	6.56	6.68

Note: PF – Primary Forest, DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, RP – Rubber Plantation, TaV – Trees around Villages, CeP *Casuarina equisetifolia* Plantation, OP – Other Plantation, OFL – Other Forest Land, RQL – Residential Quarters Land, GP – Garden Plots, AL – Agricultural Land, OL – Other Land.

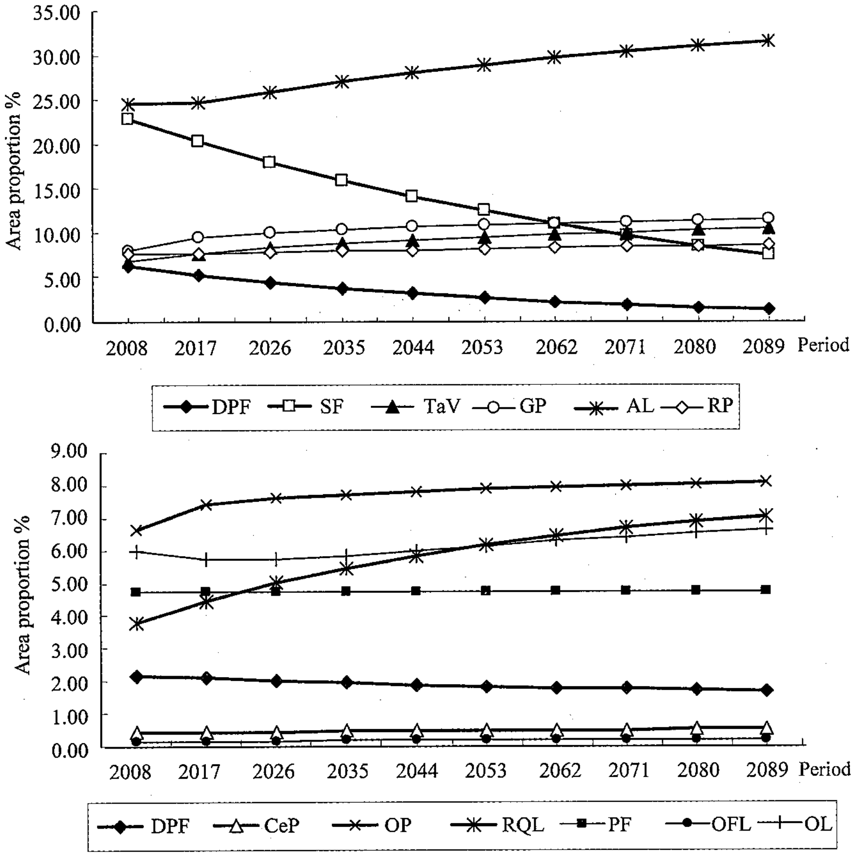

Figure 6. 2 ***Status and forecast of the occupation rate by each stage of landscape class types in Lingshui County***

7 Analyzing landscape pattern at community level

7.1 Landscape elements classification

According to result of landscape elements classification in the view of FLR in chapter 6, combining the land use of Dagan FLR demonstration area, forest landscape in Dagan FLR demonstration area was classified as 8 types: Degraded Primary Forest, Secondary Forest, Degraded Forest Land, Plantation, Non-paddy Cropland, Paddy Field, Human Settlement, Reservoir or Pond.

Maps of forest landscape mosaic of Dagan FLR demonstration area in different periods were obtained by participatory inventory, subcompartment division and inventory, using GIS tools based on RS image interpretation. The results of survey, division and maps were consulted and communicated again and again through PRA tools such as the community workshop and semi-structured interviews so as to obtain maps of forest landscape mosaic in 1990, 1999 and 2009 (see Annex 5). Different types of landscape elements should be the basis for classifying the patch boundaries for analysis of landscape pattern while different ownerships and landscape element types should be the basis for classifying the patch boundaries for identifying site-level restoration strategies.

7.2 Forest landscape pattern

The demonstration area, with a total area of 399.48 ha in 2009, lies in Qunying Town which is located in the northwest of Lingshui Li Autonomous County. There were 159 patches and the average patch area (MPS) was 2051 ha. Landscape diversity index (SDI), landscape evenness index (SEI) and landscape dominance index (D) were 1.35, 0.65 and 0.73 respectively (see Table 7.1).

Table 7. 1 ***Overall Features of Forest landscape Patterns in Dagan FLR demonstration area*** **(*in* 2009)**

Index	Area (ha)	NP (n)	PD (n/100ha)	MPS (ha)	ED (m/ha)	MSI	SDI	SEI	D
Value	399. 48	159	39. 80	2. 51	329. 12	1. 63	1. 35	0. 65	0. 73

The demonstration area was a heterogeneous forest landscape in which-Plantation was the matrix and other types was scattered among the matrix. Plantation was located in the north and centre of the demonstration area and Secondary forest and Degraded Primary Forest were most distributed in the southern hills at higher elevation, with less human activities. Degraded Forest Land and Non-paddy Cropland mosaicked among Plantation, Secondary forest and Degraded Primary Forest. There are 5 ponds or reservoirs in the area. Paddy Field was distributed along the river or around the reservoir and Human Settlement was distributed in the basin. The landscape had serious fragmentation, especially for Degraded Primary Forest, Secondary Forest and Degraded Forest Land. The map of landscape mosaic showed that Plantation dominated the overall pattern and distributed along the river or around the reservoir with important ecological interest, but Degraded Primary Forest with high biodiversity only distributed in the peak of southern or eastern hills not access to the forest and thereby the landscape has low heterogeneity.

Features of forest landscape elements in 2009 were shown in Table 7. 2. The area of Plantation was 240. 30 ha with 14 patches, which was the largest landscape element type, accounting for 60. 15% of the total area of landscape. Followed by Secondary Forest, its area was 47. 55 ha with 43 patches, accounting for 11. 90% of total area. The area of Degraded Primary Forest was 42. 06ha, 10. 53% of total area. The area proportion of Paddy Field and Degraded Forest Land were 6. 71% and 4. 53% ranking forth and fifth. The areas of Non-paddy Field, Human Settlement and Reservoir or Pond were 15. 32 ha, 8. 32 ha and 1. 00 ha respectively. The number of patches of Non-paddy Field was more than that of Human Settlement or Reservoir or Pond.

From the distribution point of view, Plantation in the demonstration area nearly filled the entire space, especially in central and northern regions. Secondary Forest were concentrated in the southwest and mostly scattered among plantations, resulting in the typical mosaic pattern plantation-secondary forest. Degraded Primary Forest were mainly distributed in hill peaks in south or southeast which have not developed for some limiting factors, such as poor transport, far away from water sources, poor soil, etc. Degraded Forest Land was mainly from deserted land after development and distributed in the south of the demonstration area and in mosaic among Degraded Primary Forest.

Table 7.2 ***Features of Forest landscape elements in Dagan FLR demonstration area in* 2009**

Landscape type	CA (ha)	PLAND%	NP (n)	PD (n/100ha)	MPS (ha)	ED (m/ha)	MSI
PDF	42.06	10.53	6	14.27	7.01	320.19	2.21
SF	47.55	11.90	43	90.43	1.11	519.63	1.68
DFL	18.11	4.53	37	204.31	0.49	684.69	1.44
P	240.30	60.15	14	5.83	17.16	222.24	1.94
NpC	15.32	3.83	30	195.82	0.51	671.17	1.45
PF	26.82	6.71	21	78.30	1.28	511.79	1.82
HS	8.32	2.08	3	36.06	2.77	317.70	1.63
RoP	1.00	0.25	5	500.00	0.20	843.99	1.27

Note: DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, P – Plantation, NpC – Non-paddy Cropland, PF – Paddy Field, HS – Human Settlement, RoP – Reservoir or Pond.

Related to the distribution of Degraded Forest Land and Non-paddy Field, these two types had the highest degree of fragmentation with small average patch area and big ED because both types were got the most frequent human activities, of which the PD and MPS of Degraded Forest Land were 204.31/100 ha and 0.49 ha. The fragmentation of Secondary Forest was much more severe for its division by Degraded Forest Land and Non-paddy Field. Its MPS was 1.11 ha with irregular boundary. The PD of Degraded Primary Forest was 14.27 /100 ha, which showed that it had less human interventions. The PD and ED of Plantation were the smallest and its MPS was 17.16 ha, showing plantation had the lowest fragmentation because of the continuous large area of betel nut and rubber tree planting instead of less human disturbances.

7.3 Forest landscape dynamics

7.3.1 Change on general features of landscape

The demonstration area showed different trends in the period of 1991 - 1999 and 1999 - 2008 (see Table 7.3). Non-paddy Field andDegraded Primary Forest were the matrix of the demonstration area in 1990. The number of patches had increased from 124 to 162 and patch density, edge density, mean patch shape index had also increased significantly while the MPS had decreased from 3.22 ha in 1990 to 2.47 ha in 1999, showing that the landscape fragmentation had become more severely, the boundaries of each patch had become more irregular in this period. With the increase of Plantation and the reduction of Degraded Primary Forest and Secondary Forest, Plantation, Non-paddy Field and Degraded Primary Forest have become the main types in the landscape in 1999 and landscape dominance decreased. This result can also be got from changes on SDI, SEI and D. SDI has increased from 1.45 in 1990 to 1.54 while SEI from 0.70 to 0.74. During the period of 1999 to 2009, the number of patches in demonstration area has reduced from 162 to 159 while MPS has increased from 2.47 ha to 2.51 ha, which indicated that landscape fragmentation and landscape heterogeneity decreased. The decrease of MSI also showed that the shape of patches has become regular. The SDI and SEI were 1.35 and 0.65 respectively in 2009. With the sharply increase of Plantation during 1999 to 2009, Non-paddy Field only distributed among plantations and would not be the main type any more. Plantation was the main type in demonstration area while degraded primary forest only distributed in hills not easy to access for local people.

Table 7.3 *Changes on general features of Dagan FLR demonstration area*

Period (year)	Area (ha)	NP (n)	PD (n/100ha)	ED (m/ha)	MSI	SDI	SEI	D
1990	399.48	124	31.04	309.73	1.74	1.45	0.70	0.63
1999	399.48	162	40.55	388.47	1.85	1.54	0.74	0.54
2009	399.48	159	39.80	329.12	1.63	1.35	0.65	0.73

7.3.2 Change on landscape element types

Changes on landscape pattern of Dagan demonstration area are mainly reflected in the decrease of Non-paddy Field, Degraded Primary Forest and the increase of Plantation. The loss of Degraded Primary Forest and the expansion of Plantation has taken place during 1990 to 1999 while the loss of Non-paddy Field and the expansion of Plantation has taken place during 1999 to 2009 (see Table 7. 4 and Figure 7. 1). The type with greatest change is Plantation which has increased 208. 88ha from 1990 to 2009 and this kind of change has mainly taken place in the period of 1999 –2009, indicating the intervention of human activities on the landscape has enhanced.

Table 7. 4 ***Changes on areas of different landscape element types in Dagan FLR demonstration area* (1990 – 2009)**

Landscape type	CA(hm^2)			PLAND%			changes of area %		
	1990	1999	2009	1990	1999	2009	1990 – 1999	1999 – 2009	1990 – 2009
PDF	97. 64	68. 42	42. 06	24. 44	17. 13	10. 53	-7. 31	-6. 6	-13. 91
SF	34. 42	29. 83	47. 55	8. 62	7. 47	11. 90	-1. 15	4. 43	3. 28
DFL	5. 68	4. 67	18. 11	1. 42	1. 17	4. 53	-0. 25	3. 36	3. 11
P	31. 42	87. 57	240. 3	7. 87	21. 92	60. 15	14. 05	38. 23	52. 28
NpC	194. 17	172. 84	15. 32	48. 61	43. 27	3. 83	-5. 34	-39. 44	-44. 78
PF	26. 82	26. 82	26. 82	6. 71	6. 71	6. 71	0	0	0
HS	8. 32	8. 32	8. 32	2. 08	2. 08	2. 08	0	0	0
RoP	1	1	1	0. 25	0. 25	0. 25	0	0	0
Total	399. 48	399. 48	399. 48	100	100	100	—	—	—

Note: DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, P – Plantation, NpC – Non-paddy Cropland, PF – Paddy Field, HS – Human Settlement, RoP – Reservoir or Pond.

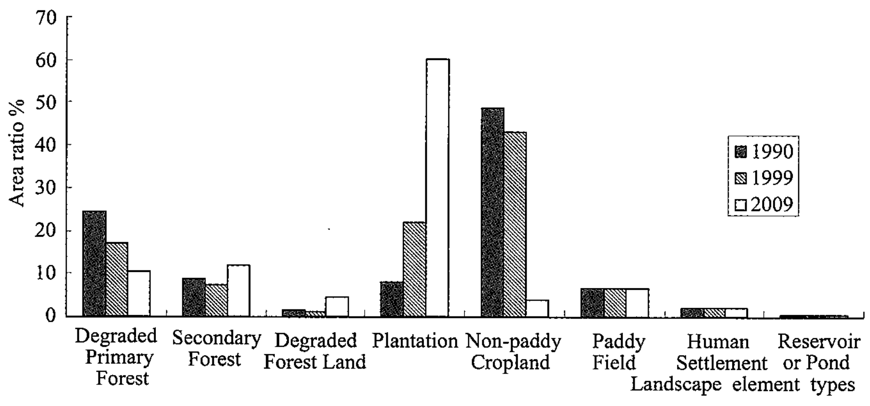

Figure 7. 1 ***Changes on areas of different landscape element types in Dagan FLR demonstration area***

Degraded Primary Forest has decreased from 97. 64 ha in 1990 to 42. 06 ha in 2009 and the percentage has dropped by 13. 91%. Different from Plantation, its changes during the two periods were similar, 29. 23 ha and 26. 36 ha respectively. Non-paddy Field has decreased from 208. 88ha from 194. 17 ha in 1990 to 15. 32 ha in 2009 and this kind of change has mainly taken place in the period of 1999 – 2009. The economic income were the main basis for land use conversion from the reduction of Degraded Primary Forest and Non-paddy Field while the expansion of Plantation. Changes on Secondary Forest and Degraded Primary Forest were similar, but Paddy Field, Human Settlement and Reservoir or Pond have kept steady for topography, climate and other natural factors.

Changes on NP (Number of patches) in Dagan demonstration area during 1990 – 2009 were mainly shown in its increase of Degraded Forest Land and Secondary and its decrease of Plantation. The increase of NP from 1991 to 1999 was mainly shown in Non-paddy Field and Plantation. The increase of NP of Degraded Forest Land and Secondary Forest and the drop of Plantation and Non-paddy Field were taken place during the period of 1999 – 2009 (see Table 7. 5 and Figure 7. 2).

Table 7. 5 ***Changes on NP of different landscape element types in Dagan FLR demonstration area from* 1990 *to* 2009**

Landscape type	Number of Patches			Percentage of NP (%)			Changes of NP (N)		
	1990	1999	2009	1990	1999	2009	1990 – 1999	1999 – 2009	1990 – 2009
DPF	9	8	6	7. 26	4. 94	3. 77	-1	-2	-3
SF	29	28	43	23. 39	17. 28	27. 04	-1	15	14
DFL	8	10	37	6. 45	6. 17	23. 27	2	27	29
P	24	36	14	19. 35	22. 22	8. 81	12	-22	-10
NpC	25	51	30	20. 16	31. 48	18. 87	26	-21	5
PF	21	21	21	16. 94	12. 96	13. 21	0	0	0
HS	3	3	3	2. 42	1. 85	1. 89	0	0	0
RoP	5	5	5	4. 03	3. 09	3. 14	0	0	0
Total	124	162	159	100	38	-3	35		

Note: DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, P – Plantation, NpC – Non-paddy Cropland, PF – Paddy Field, HS – Human Settlement, RoP – Reservoir or Pond.

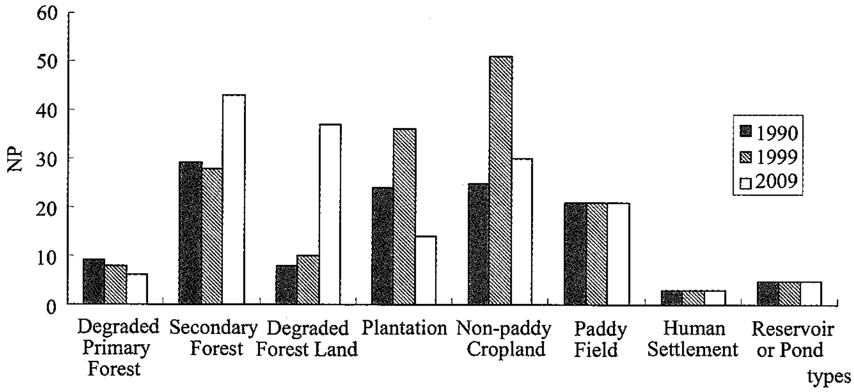

Figure 7.2 ***Changes on NP of different landscape element types in Dagan FLR demonstration area during* 1990 – 2009**

Changes on the heterogeneity of landscape element types were indicated by analysis of patch density (PD) and edge density (ED) (see Table 7.6). Changes on both patch density and edge density of different types showed the same trend during the period of 1990 – 2009. The PD and ED of Degrade Primary Forest and Non-paddy Field have increased during this period especially that of Non-paddy Field, which suggested that human disturbances to Degrade Primary Forest and Non-paddy Field have become more frequently, patch boundary has become more irregular and degree of fragmentation has increased. Different from the concentrated distribution, patches of Non-paddy Field were scattered by the division of adjacent patches, such as plantations

Table 7.6 ***Changes on PD and ED of different landscape element types in Dagan FLR demonstration area* (1990 – 2009)**

Landscape	PD(n/100ha)			ED(m/ha)		
type	1990	1999	2009	1990	1999	2009
DPF	9.22	11.69	14.27	207.68	278.76	320.19
SF	84.25	93.87	90.43	494.63	519.56	517.63
DFL	140.85	214.13	204.31	646.44	764.70	684.69
P	76.38	41.11	5.83	485.65	440.44	222.24
NpC	12.88	29.51	195.82	258.97	355.65	671.17
PF	78.30	78.30	78.30	511.79	511.79	511.79
HS	36.06	36.06	36.06	254.85	254.85	317.70
RoP	500.00	500.00	500.00	668.93	668.93	843.99

Note: DPF – Degraded Primary Forest, SF – Secondary Forest, DFL – DegradedForest Land, P – Plantation, NpC – Non-paddy Cropland, PF – Paddy Field, HS – Human Settlement, RoP – Reservoir or Pond.

and secondary forest. The PD and ED of Plantation showed a downward trend and the MPS has increased, showing that the patch boundary has become more regular and degree of fragmentation has decreased because distribution of Plantation has become more and more concentrated for the human disturbances and the constraints of management. The PD and ED of Secondary Forest and Degraded Forest Land were first increased and then decreased and that in 2009 was slightly higher than 1990. The year 1999 was a turning point for local people using these two types. Secondary Forest and Degraded Forest Land was converted to cassava and other Non-paddy Field and rubber plantations during the previous period while Non-paddy Field was first deserted and then converted to Secondary Forest and Degraded Forest Land by natural succession during the latter period. Secondary Forest and Degraded Forest Land showed different changes on fragmentation because of disturbance of development - use -desert. Fragmentation of degraded primary forest and secondary forest has led to the loss and fragmentation of habitats and thereby reduced the biodiversity in demonstration area directly.

7.4 Prediction of forest landscape dynamics

Using Markov models, transition probability matrix among different landscape element types from 1999 to 2009 was constructed to predict and analyze the forest landscape dynamics of Dagan demonstration area (see Table 7.7 and Figure 7.3). The results showed that degraded primary forest would reduce

Table 7.7 ***Status and forecast of landscape in Dagan FLR demonstration area***

Period	Occupation rate							
	Degraded primary forest	Secondary forest	Degraded Forest Land	Plantation	Non-paddy Cropland	Paddy Field	Human Settlement	Reservoir or Pond
2009	10.53	11.90	4.53	60.15	3.84	6.71	2.08	0.25
2019	6.47	14.77	4.94	62.22	2.57	6.71	2.08	0.25
2029	3.98	16.07	5.07	63.18	2.66	6.71	2.08	0.25
2039	2.45	16.59	5.13	64.05	2.75	6.71	2.08	0.25
2049	1.50	16.70	5.15	64.77	2.79	6.71	2.08	0.25
2059	1.30	16.74	5.15	65.32	2.82	6.71	2.08	0.25
2069	1.10	16.75	5.15	65.71	2.83	6.71	2.08	0.25
2079	0.92	16.75	5.15	65.91	2.84	6.71	2.08	0.25
2089	0.91	16.75	5.15	65.98	2.84	6.71	2.08	0.25

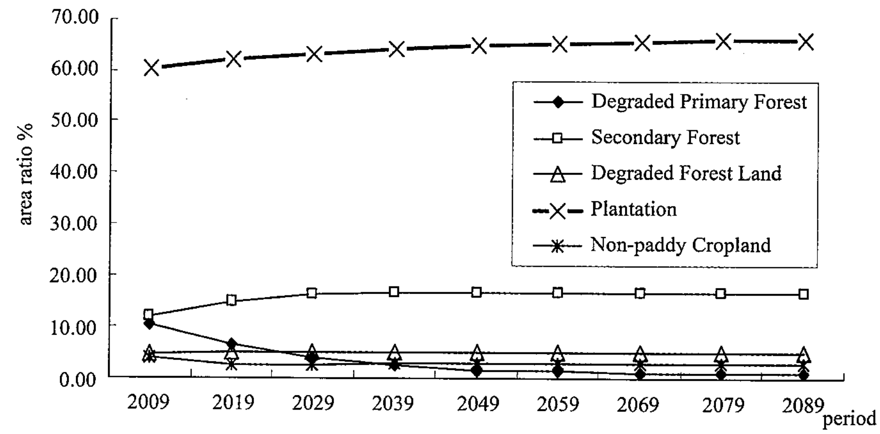

Figure 7. 3 ***Status and forecast of landscape in Dagan FLR demonstration area***

gradually from 42. 06ha in 2009 to 3. 64ha in 2089, the occupation rate (area ratio) would reduce by 9. 62% while secondary forest degraded forest land and plantation would increase slightly that would result in landscape heterogeneity decrease and the landscape would reach a relatively steady state by the year 2089. Occupation rates of degraded primary forest, secondary forest, degraded forest land, plantation and non-paddy field would be 0. 91%, 16. 75%, 5. 15%, 65. 98%, and 2. 84% respectively at steady state. Overall structure of landscape would not change fundamentally, and plantation would be the matrix and other types would mosaic, but quality and production potential of the landscape would be significantly reduced. Degrade primary forest would be developed into plantation by human disturbances driven by economic interest and traditional slash and burn farming. Degraded primary forest are mainly distributed in hill peaks with higher elevation, playing an extremely important ecological function, is the main body for ecological environment construction. The loss of degraded primary forest would bring some environment problems, such as biodiversity loss, soil erosion and thereby cause social and economic problems such as deterioration in the quality of forest products, energy shortages, and income decrease, etc. Overall, this landscape dynamics would not be consistent with socio-economic development of the demonstration area, especially the sharp reduce of degraded primary forest. Therefore, appropriate intervention should be undertaken on current landscape pattern to improve the positive direction of land use.

8 Analyzing driving forces of landscape dynamics

There are a large number of studies on forest landscape changes and its driving forces in China in recent years (Lu L et al, 2001; Zhang Y M et al, 2004; Li J G et al, 2004; Liu J Y, et al, 2009). Analysis of area changes, transition probability matrix and changes of landscape indices were main methods for studies of landscape changes (Ma R H et al, 2001; Liu J Y, et al, 2002; Song D M, 2003; Chen W B, 2004; Liu M, 2005). Qualitative analysis (Chen W B, 2004; Xu X L et al, 2004b), principal component analysis, multivariate statistical analysis and other quantitative analysis methods (Cao Y, 2004; Liu X H, 2005), Logistic regression model (Liu M et al, 2007; Xie H L, 2008) were usually used in analysis of driving forces of landscape change. Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this chapter used transition probability matrix and participatory survey method to study the driving forces of forest landscape dynamics both at region level and at community level.

8.1 Driving forces of landscape dynamics at regional level

Based on analysis of transition probability matrix, driving forces responsible for the forest landscape dynamics of Lingshui Li Autonomous County during the period of 1991 to 2008 were analyzed using PRA method such as semi-structured interview, matrix ranking and brainstorming, as well as discussions and interviews with representatives of different stakeholder groups and field survey.

Forestry policies and key programs were the dominant factors to improve the quantity and quality of forest.

"Forest Protection Management Regulations of Hainan Province" was developed on July 30, 1993. The government of Hainan Province decided to implement the logging ban on natural tropical forest and made a Policy to Coordinate Economy Development with Environment in 1994, and the Consultative Committee for Environment Protection of Hainan Province was set up. "The Natural Forest Protection Program (NFPP)" has been implemented since 1998. The People's Congress of Hainan Province made a decision on Construction Ecology Province on February 1999 and then the Standing Committee of the Provincial People's Congress approved the overall plan for ecological province construction in July. "The Conversion of Cropland to Forest Program (PCCF)" was initiated in 2002. Besides, the key forest programs also included "Wildlife Conservation and Nature Reserves Development Program", "Non-commercial Forest Protection and Construction Program (NFPCP)", "Coastal Shelterbelt Protection and Construction Program (CSPCP)", "Forest Industrial Base Development Program in Key Regions with a Focus on Fast-growing and High-yielding Timber Plantations (FIBDP)". The implementation of these key forestry programs not only controlled the decline of tropical forest, protected and restored the tropical natural forest effectively, particularly the northern Diaoluoshan National Forest area, but also helped the increase of tropical plantation and the quality of natural forest stands in the tropics. The results from forest management inventory in 1994 and forest management sampling survey in 2005 showed that the stock volume had increased by 18.2% from 175.5m^3/ha to 207.5 m^3/ha.

Reducing rural poverty through development were important factors in the changes on forest landscape in western hills area and northern middle hills region.

As the biggest project in western hills and northern middle hills region of Lingshui Li Autonomous County, Reducing rural poverty through development has become the major force driving the landscape dynamics. To complete the goals and tasks advanced by the "China Rural Poverty Alleviation and Development Outline (2001 – 2010)", according to the poverty alleviation pilot requirements in "cadre training plan in poverty-stricken areas in 2006", Lingshui Li Autonomous County developed the planting base construction taking industrialization-oriented poverty relief as breakthrough. 15 rubber planting bases and 10 betelnut bases have been developed in Qunying Town and Benhao Town, totally constructed 1,333 ha rubber plantations and 533 ha betelnut plantations under government support. In 2008, 800,000 RMB was invested in

Benhao Town and Longguang Town to plant 280, 000 betelnut seedlings with an area of 167 ha. Meanwhile, 500,000 RMB was invested in Benhao Town, Longguang Town and Qunying Town to plant 120, 000 rubber tree seedlings. In order to meet farmer needs, 500,000 RMB was invested to support the poor to manage rubber plantation of 200 ha, betel nut of 133 ha, and mango of 200 ha.

Although the poverty relief way that make full use of resources in poverty-stricken areas increased the economic development in rural area, such as 46 poverty-stricken villages and civilized ecological villages have been supported, the development of planting bases relied on land-use conversion, resulting in the conversion of degraded primary forests, secondary forest, degraded forest land, agricultural land in the planting area to plantation and garden plots.

Livelihood development was an important factor in the changes on forest landscape in the whole hills area and middle hills region.
As one of the national poverty-stricken counties, Lingshui Li Autonomous County is a backward economic county and people live in poverty. Agricultural land in the whole hilly area and middle hills region are limited so that development of economic crops has become the major choice for subsistence. Furthermore, "slash and burn" (shifting cultivation agriculture), traditional farming of Li Nationality, was the major driving force for landscape change and resulted in the diminishing of degraded primary forest and secondary forest.

Village greening and farm-shelter were important factors in the changes of forest landscape in central plain terrain.
Trees around villages increased gradually for new rural construction and ecological civilization construction. The need of windbreak and farmland protection was the important factor in the formation of fame-shelter undesignedly in central plain terrain. With the continuous construction, trees around villages and farm-shelter have become the important ecological security barrier in central plain terrain.

Sand excavation, pond culture and tourism development are important driving forces for changes on forest landscape in coastal area.
There were large area of coastal shelterbelt forest and the *Casuarina equisetifolia* forest in Lingshui Li Autonomous County in the early 1990s. But coastal

shelterbelt forest had suffered from severe damage and the area had decreased sharply because of titanium mining during 1991 – 1994. And then the forest has been restored due to the campaign of " wiping out the barren hills" in the province. However, the coastal shelterbelt forests were damaged severely once again due to conversion to shrimp-farming ponds or watermelon fields for economic interests since 2004, because high income can be generated from shrimp-farming and watermelon industry. The 3rd Hainan Province Standing Committee of People's Congress has approved the "Regulations on Coastal Shelterbelt Forest Protection and Construction in Hainan Province" on November 29, 2007. At present, coastal shelterbelt forest restoration has been referred to one of the "three Lingshui" targets, particularly the target of ecological county. According to the notice "[2007] 9" to strengthen the protection of coastal shelterbelt forest, any group or individual should not occupy forest land within 200 m wide from high tide line, key projects at or above province level which have to expropriate and occupy the forest land must keep at least 100 m wide shelterbelt forest and deal with the land use change in accordance with law. Restoration of the coastal shelterbelt forest is conducted through the "returning pond fishery back to forest" and other projects. Planting watermelon understory is also controlled strictly without affecting normal growth of the forest. Tourism development will affect the development of coastal shelterbelt forest to some extent in recent years.

8.2 Driving forces of landscape dynamics at community level

Similar to analysis of dominant forces responsible for forest landscape changes at region level, the driving forces of forest landscape in Dagan FLR demonstration area was analyzed by communication and discussion with villagers using PRA tools such as community workshop semi-structured interviews, resources mapping, matrix ranking and problem causal analysis based on analysis of transition probability matrix in different periods.

Basic living allowances

Basic living allowances and expansion of agricultural land were the dominant factors to drive the changes on forest landscape in Dagan FLR demonstration area. Cultivated land in demonstration area is only 0.04 ha. Most of the residents in Dagan FLR demonstration area were short of food and clothing in the early of 1990s. Even today there are still a few villagers having the problem of food shortages for 2 months a year. In order to solve the problem of food and clothing shortages, local residents developed the degraded primary forest and secondary forest into cassava fields in 1990s, especially during the period of 1990 – 1999. However, energy needs of life necessities have run throughout the study period, so firewood has played an important part in the change of forest landscape because electricity, coal, gas and other alternative energy sources were seldom used.

Policies of poverty alleviation

The main form of policies of poverty alleviation was to provid seedlings for non-timber forest plantation, which caused the conversion from agriculture land such as cassava to lychee, mango and other non-timber forest and rubber, betel nut plantation. Villagers have great enthusiasm on these policies so that they planted rubber tree and betel nut trees along roads and streams and other areas which were agricultural lands before. In order to increase efforts of poverty alleviation for the poor minority areas, Lingshui Li Autonomous County implemented the policies of poverty alleviation in the form of providing seedlings and trainings during the period of 1990 – 1999. This contributed to the conversion to plantation from degraded and secondary forest. Policies of poverty alleviation turned to develop rubber, nuts and other industries based on existing technology and management experience after 1999, resulting in great increase of rubber, betel nut and other plantation during 1999 – 2009. With increasing efforts in poverty reduction, improvement of living standards and increased economic benefits of rubber and betel nut trees, most secondary forest developed from deserted cassava fields have been converted to plantations. Meanwhile, some existing secondary forests are still in the risk of deforestation driven by economic interests. This is the key trade-off needs to be considered in the FLR at community level, which is the conflict between plantation expansion and secondary forest protection.

Prices of forest products

Prices of forest products as driving force for forest landscape change in the demonstration area mainly happened in the period of 1999 – 2009. Prices of rubber, betel nut and *Eucalyptus* trees have increased steadily in recent 5 years. Villagers are able to get sufficient basic subsistence for their lives and do not rely on expanding the cassava or corn fields to make lives. So agricultural fields developed before were converted to plantations and rubber trees, betel nut trees and *Eucalyptus* have become the favorite species. Another effect was that degraded primary forest, secondary forest or degraded forest land were converted into plantations directly in this period and non-paddy field was not the transition between degraded and secondary forest and plantation, which indicated the strong desire of residents to expand the planted forest.

Traditional practices

Traditional practices were important factors in the changes on forest landscape in demonstration area. As Li minority village, every family in demonstration area should set aside a certain area of land for unmarried men. Therefore, families having boys would reclaim as much land as possible, resulting in the conversion from degraded primary forest to agricultural fields or plantation. Farmers have mentioned that children would ask parents for enough land to survive their future families when they grow up. Another traditional practice is that the user right of a land would belong to the developer as long as the land was developed. Field survey has found that couch grass, stones or shrubs were used to mark the boundaries of developed but not planted land.

9 Analysis of characteristics of degraded and secondary forests and restoration strategies

The specific activities of FLR initiative should be implemented at site level whether for regional level FLR or community-level FLR. Compared to other restoration approaches, FLR puts emphasis on the restoration and management of degraded and secondary forests (ITTO and IUCN, 2005). Categories of degraded and secondary forest were defined in "ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forest" published in 2002, including degraded primary forest, secondary forest and degraded forest land. Degraded and secondary forests tend to be located in more accessible areas close to human settlements and are used more than primary forests. Thus they are an increasingly important component of the forest resource in the tropics, providing special economic functions for the poor people living in rural areas (Banerjee A, 1995; Gilmour D A, 2000; Mcshea W J, 2009).

China has done some important studies on biodiversity, community structure and dynamics of degraded primary forest (Li Y D, 1997; An S q et al, 1999; Zang R G et al, 2002; Ding Y, 2007; Yang Y C, et al, 2008; Xu H, et al, 2009), as well as types, characteristics and management status of secondary forest (Huang S N et al, 2000; Hou Y Z, 2003; He B X et al, 2008; Hou Y Z et al, 2008; Wang H F, 2008), but few studies focused on community and measuration characteristics of tropical degraded and secondary forest in view of forest management. Characteristics of degraded and secondary forest in Dagan FLR demonstration area in Lingshui Li Autonomous County were analyzed from forest management perspective based on fully understanding of the definitions of different forest categories and site-level restoration strategies were identified, so as to provide foundation for protection, restoration, sustainable management and use of degraded and secondary forest.

9.1 Characteristics of degraded primary forest

9.1.1 Dominant species

Importance value of plants in arbor storey of degraded primary forest in Dagan demonstration area was shown in Table 9.1. There were totally 42 tree species in the arbor storey of community of *Garcinia oblongifolia- Hopea exalata*. The importance value of *Garcinia oblongifolia* was 41.05%, which was the biggest. Followed by *Hopea exalata*, its important value was 34.98%. The importance values of *Engelhardtia roxburghiana*, *Ixonanthes chinensis*, *Diospyros potingensis*, *Acronychia oligophlebia*, *Canarium album*, *Symplocos lancifolia* and *Ficus henryi* ranked 3 – 9 respectively while those of other 33 species were less than 10%. There were totally 26 tree species in arbor storey of community *Engelhardtia roxburghiana* - *Garcinia oblongifolia*. The importance value of *Engelhardtia roxburghiana* was 70.94%, which was the biggest. Followed by *Garcinia oblongifolia* and *Ixonanthes chinensis*, the importance values were 55.21% and 35.50% respectively. The importance values of *Symplocos lancifolia*, *Lithocarpus pseudovestitus*, *Sarcosperma laurinum*, *Ficus microcarpa*, *Dalbergia hainanensis*, *Diospyros potingensis* and *Dalbergia odorifera* ranked 4 –10 respectively. There were totally 35 tree species in arbor storey of community *Amesidodendron chinense* - *Garcinia oblongifolia*. The importance value of *Amesidodendron chinense* was 48.16%, which was the biggest one. Followed by *Garcinia oblongifolia*, the importance values was 42.14%. The importance values of *Engelhardtia roxburghiana*, *Lithocarpus pseudovestitus*, *Gonocaryum lobbianum*, *Polyspora balansae* and *Symplocos lancifolia* ranked 3 –7 respectively. There were totally 21 tree species in arbor storey of community *Sarcosperma laurinum*, *Dalbergia hainanensis* - *Polyalthia laui*. The importance value of *Sarcosperma laurinum* was 33.21%, which was the biggest one. Followed by *Dalbergia hainanensis*, *Polyalthia laui*, *Elaeocarpus sylvestris* and *Diospyros susarticulata*, ranking 2 – 5 respectively.

Tree species in arbor storey of 4 communities are mainly from families asEuphorbiaceae, Moraceae, Theaceae, Lauraceae, Fagaceae, Ebenaceae, Papilionaceae and Dipterocarpaceae. There were some valuable native species in Hainan Province, such as *Dalbergia odorifera* (endangered species with special type of wood), *Vatica mangachapoi* (vulnerable species with first class wood), *Litchi chinensis* (vulnerable species with special type of wood), *Hopea exalata* and *Ixonanthes chinensis* (vulnerable species), *Amesidodendron chinense* (with first class wood), etc.

Table 9.1 *Importance value of tree species in different degraded primary forests*

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community 1: *Garcinia Oblongifolia- Hopea exalata*	1	*Garcinia oblongifolia*	15.61	11.50	13.94	41.05
	2	*Hopea exalata*	16.18	12.39	6.41	34.98
	3	*Engelhardtia roxburghiana*	5.78	6.19	9.79	21.77
	4	*Ixonanthes chinensis*	5.78	4.42	6.96	17.17
	5	*Diospyros potingensis*	6.94	5.31	3.84	16.09
	6	*Acronychia oligophlebia*	6.36	6.19	2.06	14.61
	7	*Canarium album*	4.62	5.31	3.66	13.59
	8	*Symplocos lancifolia*	2.89	4.42	3.35	10.67
	9	*Ficus henryi*	1.16	0.88	8.47	10.51
	10	*Schima crenata*	2.31	2.65	3.64	8.61
	11	*Piptanthus laburnifolius*	0.58	0.88	6.73	8.20
	12	*Eriobotrya deflexa*	2.89	2.65	2.26	7.80
	13	*Lithocarpus fenzelianus*	1.73	2.65	2.88	7.27
	14	*Castanopsis fissa*	1.73	1.77	3.62	7.12
	15	*Amesidodendron chinense*	2.31	2.65	2.05	7.02
	16	*Ficus microcarpa*	1.73	2.65	1.26	5.65
	17	*Sapium discolor*	1.73	0.88	2.83	5.45
	18	*Gonocaryum lobbianum*	1.73	2.65	0.94	5.33
	19	*Lithocarpus pseudovestitus*	1.16	1.77	2.06	4.98
	20	*Vatica mangachapoi*	1.16	1.77	0.83	3.76
	21	*Suregada glomerulata*	0.58	0.88	2.19	3.65
	22	*Pithecellobium clypearia*	1.16	1.77	0.70	3.63
	23	*Cinnamomum parthenoxylon*	1.16	0.88	0.91	2.95
	24	*Decaspermum albociliatum*	0.58	0.88	1.46	2.92
	25	*Ficus nervosa*	0.58	0.88	1.31	2.78
	26	*Dolichandrone cauda-felina*	0.58	0.88	1.08	2.54
	27	*Phoebe hungmaoensis*	1.16	0.88	0.48	2.52
	28	*Artocarpus tonkinensis*	0.58	0.88	0.74	2.21
	29	*Photinia benthamiana*	0.58	0.88	0.48	1.94

(continued)

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community 1: *Garcinia Oblongifolia- Hopea exalata*	30	*Euodia lepta*	0. 58	0. 88	0. 45	1. 91
	31	*Polyspora balansae*	0. 58	0. 88	0. 44	1. 90
	32	*Erythropsis. colorata*	0. 58	0. 88	0. 43	1. 90
	33	*Sarcosperma laurinum*	0. 58	0. 88	0. 42	1. 88
	34	*Codiaeum variegatum*	0. 58	0. 88	0. 28	1. 75
	35	*Cryptocarya densiflora*	0. 58	0. 88	0. 21	1. 67
	36	*Altingia obovata*	0. 58	0. 88	0. 18	1. 65
	37	*Bischoffia javanica*	0. 58	0. 88	0. 15	1. 62
	38	*Diospyros howii*	0. 58	0. 88	0. 14	1. 60
	39	*Litchi chinensis*	0. 58	0. 88	0. 11	1. 57
	40	*Toxicodendron vernicifluum*	0. 58	0. 88	0. 11	1. 57
	41	*Viburnum odoratissimum*	0. 58	0. 88	0. 10	1. 57
	42	*Rhus succedanea*	0. 58	0. 88	0. 03	1. 50
Community 2: *Engelhardtia roxburghiana-Garcinia oblongifolia*	1	*Engelhardtia roxburghiana*	24. 62	14. 71	31. 62	70. 94
	2	*Garcinia oblongifolia*	22. 31	11. 76	21. 14	55. 21
	3	*Ixonanthes chinensis*	10. 00	11. 76	13. 73	35. 50
	4	*Symplocos lancifolia*	5. 38	5. 88	3. 78	15. 04
	5	*Lithocarpus pseudovestitus*	4. 62	5. 88	2. 57	13. 07
	6	*Sarcosperma laurinum*	3. 85	4. 41	4. 01	12. 27
	7	*Ficus microcarpa*	3. 85	4. 41	3. 16	11. 42
	8	*Dalbergia hainanensis*	2. 31	4. 41	3. 81	10. 53
	9	*Diospyros potingensis*	3. 08	5. 88	1. 53	10. 49
	10	*Dalbergia odorifera*	3. 85	2. 94	3. 67	10. 46
	11	*Radermachera hainanensis*	2. 31	2. 94	1. 74	6. 99
	12	*Canarium album*	2. 31	2. 94	1. 34	6. 59
	13	*Lannea coromandelica*	1. 54	2. 94	0. 89	5. 37
	14	*L iquidambar formosana*	0. 77	1. 47	2. 93	5. 17
	15	*Schima crenata*	0. 77	1. 47	0. 65	2. 89
	16	*Photinia benthamiana*	0. 77	1. 47	0. 60	2. 84
	17	*Bischoffia javanica*	0. 77	1. 47	0. 51	2. 75
	18	*Suregada glomerulata*	0. 77	1. 47	0. 46	2. 70
	19	*Acronychia oligophlebia*	0. 77	1. 47	0. 45	2. 69
	20	*Sterculia lanceolata* Cav.	0. 77	1. 47	0. 33	2. 57
	21	*Gonocaryum lobbianum*	0. 77	1. 47	0. 30	2. 54

(continued)

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	22	*Polyspora balansae*	0.77	1.47	0.22	2.46
	23	*Syzygium rysopodum*	0.77	1.47	0.18	2.42
	24	*Glochidion dasyphyllum*	0.77	1.47	0.18	2.42
	25	*Elytranthe cochinchinensis*	0.77	1.47	0.14	2.38
	26	*Sindora glabra*	0.77	1.47	0.03	2.27
Community 3: *Amesidodendron chinense* - *Garcinia oblongifolia*	1	*Amesidodendron chinense*	14.29	12.12	21.75	48.16
	2	*Garcinia oblongifolia*	17.01	14.14	10.99	42.14
	3	*Engelhardtia roxburghiana*	4.76	6.06	7.63	18.45
	4	*Lithocarpus pseudovestitus*	5.44	4.04	7.23	16.71
	5	*Gonocaryum lobbianum*	6.12	4.04	6.4	16.56
	6	*Polyspora balansae*	6.12	6.06	4.18	16.36
	7	*Symplocos lancifolia*	5.44	7.07	3.16	15.67
	8	*Cleistocalyx conspersipunctatus*	1.36	2.02	7.12	10.50
	9	*Ficus microcarpa*	4.08	3.03	2.47	9.58
	10	*Radermachera hainanensis*	3.4	3.03	2.85	9.28
	11	*Hopea exalata*	3.4	4.04	0.75	8.19
	12	*Canarium album*	2.72	3.03	0.94	6.69
	13	*Litsea lancilimba*	2.72	2.02	1.7	6.44
	14	*Ixonanthes chinensis*	2.04	2.02	1.03	5.09
	15	*Sarcosperma laurinum*	2.04	2.02	0.66	4.72
	16	*Machilus chinensis*	0.68	1.01	1.45	3.14
	17	*Lindera playfairii*	1.36	1.01	0.51	2.88
	18	*Machilus nakao*	0.68	1.01	1.03	2.72
	19	*Pentaphylax euryoides*	1.36	1.01	0.23	2.6
	20	*Ehretia acuminata*	0.68	1.01	0.85	2.54
	21	*Toxicodendron vernicifluum*	0.68	1.01	0.73	2.42
	22	*Bischoffia javanica*	0.68	1.01	0.63	2.32
	23	*Pithecellobium clypearia*	0.68	1.01	0.6	2.29
	24	*Diospyros potingensis*	0.68	1.01	0.48	2.17
	25	*Sindora glabra*	0.68	1.01	0.36	2.05
	26	*Photinia benthamiana*	0.68	1.01	0.36	2.05
	27	*Eriobotrya deflexa*	0.68	1.01	0.36	2.05
	28	*Piptanthus laburnifolius*	0.68	1.01	0.33	2.02
	29	*Phoebe hungmaoensis*	0.68	1.01	0.21	1.9

(continued)

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	30	*Litchi chinensis*	0.68	1.01	0.19	1.88
	31	*Caryota mitis*	0.68	1.01	0.17	1.86
	32	*Peltophorum tonkinense*	0.68	1.01	0.16	1.85
	33	*Ficus auriculata*	0.68	1.01	0.16	1.85
	34	*Acronychia oligophlebia*	0.68	1.01	0.1	1.79
	35	*Pterospermum heterophyllum*	0.68	1.01	0.1	1.79
Community 4: *Sarcosperma laurinum*, *Dalbergia hainanensis* - *Polyalthia laui*	1	*Sarcosperma laurinum*	12.82	12.90	7.49	33.21
	2	*Dalbergia hainanensis*	5.13	6.45	17.99	29.57
	3	*Polyalthia laui*	12.82	9.68	3.43	25.93
	4	*Elaeocarpus sylvestris*	5.13	3.23	16.74	25.10
	5	*Diospyros susarticulata*	5.13	6.45	9.66	21.24
	6	*Antirhea chinensis*	5.13	6.45	4.72	16.30
	7	*Garcinia oblongifolia*	7.69	6.45	1.65	15.80
	8	*Cratoxylum cochinchinense*	2.56	3.23	8.88	14.67
	9	*Wendlandia merrilliana*	5.13	6.45	2.27	13.85
	10	*Ficus variolosa*	7.69	3.23	2.64	13.56
	11	*Lithocarpus elmerrillii*	2.56	3.23	7.02	12.81
	12	*Ormosia pinnata*	2.56	3.23	4.04	9.83
	13	*Lithocarpus corneus*	5.13	3.23	1.19	9.55
	14	*Syzygium buxifolium*	2.56	3.23	2.85	8.64
	15	*Vitex tripinnata*	2.56	3.23	2.85	8.64
	16	*Suregada glomerulata*	2.56	3.23	1.75	7.54
	17	*Acronychia oligophlebia*	2.56	3.23	1.56	7.35
	18	*Engelhardtia roxburghiana*	2.56	3.23	1.22	7.01
	19	*Goniothalamus howii*	2.56	3.23	0.99	6.78
	20	*Neolitsea obtusifolia*	2.56	3.23	0.74	6.53
	21	*Phoebe henryi*	2.56	3.23	0.30	6.09

9.1.2 Community structure

The community of degraded primary forest had the structure of stratified uneven-aged forest, composed by arbor storey, shrub storey and grass storey, and the canopy density is 1.0. The arbor storey can be classified as two sub-storeys, one with H (tree height) larger than 8 m while the other with H less than 8 m. Most of valuable trees in the sub-storey I in arbor storey have been used while there are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey had rich species, such as *Dalbergia odorifera*, *Sarcosperma laurinum*, *Ormosia pinnata*, *Lithocarpus elmerrillii*, *Dolichandrone cauda-felina*, *Cryptocarya densiflora*, *Engelhardtia roxburghiana* and other tree saplings, as well as *Ervatamia officinalis*, *Aporosa chinensis* and other shrub species. Species in grass storey were *Psychotria rubra*, *Elaeocarpus petiolatus*, *Garcinia oblongifolia*, *Livistona chinensis*, *Aporosa chinensis* and other seedlings, and grass species as *Indocalamus latifolius* and *Chrysopogon aciculatus* . In addition, the community of degraded primary forest has rich vines, such as *Smilax china*, *Piper hainanense* and *Abrus mollis* . Thus shrub storey and grass storey in each forest stand still have valuable tree saplings and seedlings.

9.1.3 Species diversity of arbor storey

Species diversity of arbor storey in different communities of degraded primary forest inthe demonstration area was shown in Table 9.2. Species Richness (R) of communities 1 -4 were 42, 26, 35 and 21respectively. Diversity index (SW) were 4.46, 3.61, 4.28 and 4.14 respectively. The Evenness (E) of communities were 0.81, 0.77, 0.81 and 0.94 while Ecological Dominance (ED) were 0.07, 0.13, 0.07 and 0.04 respectively.

On the whole, Species Richness (R) in arbor storey of degraded primary forest was lower than that of adjacent tropical lowland rainforest in Baishui forestry farm and Nanxi forestry farm located in Diaoluoshan Nature Reserve (Huang K Y, 2007). Diversity index was close to that of low-elevation tropical forest in Diaoluoshan Nature Reserve (4.04 -4.17), but less than that of tropical primary forest in Jianfengling Mountain (5.78 - 6.28) (Li Y D, 1997; Xu H, et al, 2009).

Tab. 9.2 Species diversity in tree stratum of degraded primary forests

Community	Forest storey	R	SW	ED	E
Community 1	Arbor storey	42	4.46	0.07	0.81
	Sub storey Ⅰ	30	4.39	0.06	0.89
	Sub storey Ⅱ	29	3.89	0.10	0.80

(continued)

Community	Forest storey	R	SW	ED	E
Community 2	Arbor storey	26	3.61	0.13	0.77
	Sub storey I	12	2.83	0.18	0.79
	Sub storey II	24	3.73	0.11	0.81
Community 3	Arbor storey	35	4.28	0.07	0.81
	Sub storey I	25	3.93	0.08	0.85
	Sub storey II	27	2.60	0.10	0.55
Community 4	Arbor storey	21	4.14	0.04	0.94
	Sub storey I	6	2.50	0.07	0.97
	Sub storey II	15	3.64	0.06	0.93

9.1.4 Stand growth

Degraded primary forest stand growth was shown in Table 9.3. The average DBH of arbor storey of 4 communities was 10.2 – 14.3 cm and the average height was 8.50 – 13.39 m. The average volume per unit area was 142.51 – 199.44 m^3/ha, significantly lower than that of mountain rainforest in Bawangling, Hainan Island (Jiang Y X and Lu J P, 1991; Huang Q L, 2001; Huang Q L et al, 2002). Stand density was 2321 – 3545 N/ha, higher than that of primary forest of mountain rainforest in Bawangling. Trees were mostly in sub storey II and the number of trees in sub storey II accounted for 48.30 – 79.49% of the total number of trees in degraded primary forest communities. However, the volume of trees in sub storey I accounted for 67.11 – 91.38% of the total volume.

Table 9.3 ***Forest mensuration factors of degraded primary forests***

Community	Forest storey	average DBH(cm)	average H(m)	Stand density		Volume	
				Density (N/ha)	Percentage (%)	Volume (m^3/ha)	Percentage (%)
Community 1	Arbor storey	12.68	12.33	2595	100	191.55	100
	Sub storey I	17.65	14.23	1005	38.73	164.28	85.77
	Sub storey II	8.09	6.60	1590	61.27	27.27	14.23
Community 2	Arbor storey	10.20	10.05	3545	100	142.51	100
	Sub storey I	14.29	12.22	1091	30.77	103.30	72.48
	Sub storey II	7.71	6.75	2455	69.23	39.21	27.52

(continued)

Community	Forest storey	average DBH(cm)	average H(m)	Stand density		Volume	
				Density (N/ha)	Percentage (%)	Volume (m^3/ha)	Percentage (%)
Community 3	Arbor storey	13.16	13.39	2321	100	199.44	100
	Sub storey Ⅰ	16.79	14.62	1200	51.70	183.17	91.38
	Sub storey Ⅱ	7.52	6.83	1121	48.30	17.27	8.62
Community 4	Arbor storey	14.30	8.50	2925	100	195.12	100
	Sub storey Ⅰ	24.06	10.29	600	20.51	130.94	67.11
	Sub storey Ⅱ	10.74	6.18	2325	79.49	64.18	32.89

9.1.5 DBH distribution

As shown in Table 9.4 and Figure 9.1, the DBH distribution range of degraded primary forests was 4 – 48 cm and the maximum diameter was 46.30 cm. The number of trees in diameter class 4cm didn't include trees with DBH of 2 – 4.9cm, so the number of trees in diameter class 4cm was lower than that of diameter class 8cm significantly. The DBH distribution of each degraded primary forest community showed the inverse J shape.

Table 9.4 ***The DHB distribution ofdegraded primary forests***

Diameter class (cm)	The number of trees in each diameter class (n)			
	Community 1	Community 2	Community 3	Community 4
4	20	17	11	11
8	35	48	36	37
12	24	21	30	23
16	10	7	12	14
20	6	6	5	7
24	3	1	2	4
28	1	0	1	3
32	0	0	2	2
36	0	0	1	0
40	0	0	1	0
44	1	0	0	0
48	1	0	0	0

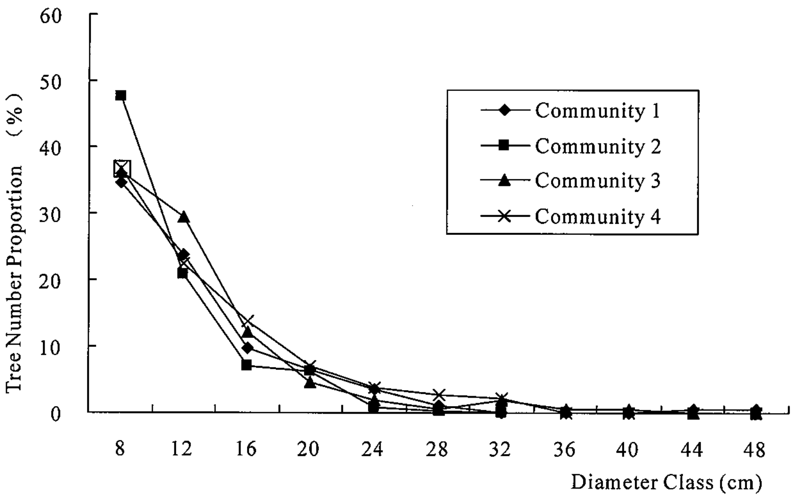

Figure 9. 1 ***The DHB distribution ofdegraded primary forests***

9. 2 Characteristics of secondary forest

9. 2. 1 Dominant species

Importance value of plants in arbor storey of secondary forest in Dagan demonstration area was shown in Table 9. 5. Relative dominance was calculated using Ground Diameter other than DBH for theimportance value calculation of community *Symplocos laurina- Radermachera hainanensis* and community *Lithocarpus pseudovestitus* . There were totally 25 tree species in arbor storey of community *Aporosa chinensis* . The importance value of *Aporosa chinensis* was 60. 32% , which was the biggest one. Followed by *Lithocarpus corneus* and *Garcinia oblongifolia*, the importance values were 23. 58% and 22. 38% respectively. The importance values of *Liquidambar formosana*, *Lithocarpus howii*, *Artocarpus tonkinensis*, *Castanopsis hainanensis*, *Syzygium buxifolium*, *Ormosia pinnata*, *Ellipanthus glabrifolius* and *Sapium discolor* ranked 4 – 11 respectively while those of other 14 species were less than 10%. There were totally 6 tree species in arbor storey of community *Trema tomentosa* and species *Trema tomentosa* had the biggest importance value, which was up to 195. 09%. The importance values of *Indigofera galegoides*, *Helicteres hirsuta*, *Ellipanthus glabrifolius*, *Evodla meliaefolia* and *Aporosa chinensis* decreased in turns. There were totally 12 tree species in arbor storey of community *Symplocos laurina- Radermachera hainanensis* . The important value of *Symplocos* laurina was 78.39%, which was the biggest one. Followed by *Radermachera hainanensis* withan importance value of 58.75%. The importance values of *Photinia benthamiana*, *Chukrasia tabularis* and *Lannea coromandelica* ranked 3–5 respectively. There were totally 32 tree species in arbor storey of community *Lithocarpus pseudovestitus*. The importance value of *Lithocarpus pseudovestitus* was 48.67%, which was the biggest one. Followed by *Sterculia lanceolata* with an importance value of 20.50%. The importance values of *Sapium discolor*, *Canarium album*, *Memecylon ligustrifolium*, *Glochidion dasyphyllum*, *Sindora glabra*, *Suregada glomerulata* and *Glochidion wrightii* ranked 3–9 respectively while those of other 23 species were less than 10%.

Tree species in arbor storey of 4 communities are mainly from families asEuphorbiaceae, Fagaceae, Ulmaceae, Bignoniaceae, Sterculiaceae and Papilionaceae. There were some valuable native species in Hainan Province, such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, and important species for commercial forest in Hainan Province, such as *Trema tomentosa*, as well as afforestation species like *Dolichandrone cauda-felina*, etc.

Table 9.5 ***Importance value of plant species in different secondary forest communities***

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
Community1: *Aporosa chinensis*	1	*Aporosa chinensis*	30.77	12.50	17.05	60.32
	2	*Lithocarpus corneus*	8.97	6.25	8.36	23.58
	3	*Garcinia oblongifolia*	10.26	6.25	5.87	22.38
	4	*Liquidambar formosana*	2.56	3.13	13.01	18.70
	5	*Lithocarpus howii*	7.69	3.13	4.72	15.54
	6	*Artocarpus tonkinensis*	2.56	3.13	9.74	15.43
	7	*Castanopsis hainanensis*	2.56	6.25	3.93	12.74
	8	*Syzygium buxifolium*	1.28	3.13	7.71	12.12
	9	*Ormosia pinnata*	2.56	6.25	2.90	11.71
	10	*Ellipanthus glabrifolius*	3.85	3.13	4.10	11.07
	11	*Sapium discolor*	1.28	3.13	5.71	10.12
	12	*Ormosia fordiana*	2.56	3.13	3.90	9.59
	13	*Indigofera galegoides*	3.85	3.13	1.95	8.92

(continued)

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	14	*Cratoxylum. cochinchinense*	2.56	3.13	1.54	7.23
	15	*Wrightia pubescens*	2.56	3.13	1.12	6.80
	16	*Beilschmiedia intermadida*	2.56	3.13	1.01	6.70
	17	*Lannea coromandelica*	1.28	3.13	1.78	6.19
	18	*Lithocarpus elmerrillii*	1.28	3.13	1.23	5.63
	19	*Memecylon ligustrifolium*	1.28	3.13	1.07	5.48
	20	*Acronychia oligophlebia*	1.28	3.13	0.93	5.34
	21	*Dalbergia hainanensis*	1.28	3.13	0.87	5.27
	22	*Glochidion puberum*	1.28	3.13	0.45	4.85
	23	*Psychotria rubra*	1.28	3.13	0.38	4.79
	24	*Radermachera frondosa*	1.28	3.13	0.36	4.76
	25	*Aodoratissima*	1.28	3.13	0.32	4.72
Community 2: *Trema tomentosa*	1	*Trema tomentosa*	77.27	37.50	80.32	195.09
	2	*Indigofera galegoides*	9.09	12.50	10.10	31.69
	3	*Helicteres hirsuta*	9.09	12.50	3.68	25.27
	4	*Ellipanthus glabrifolius*	1.52	12.50	4.02	18.03
	5	*Evodla meliaefolia*	1.52	12.50	1.21	15.22
	6	*Aporosa chinensis*	1.52	12.50	0.68	14.69
Community3: *Symplocos laurina-Radermachera hainanensis*	1	*Symplocos laurina*	29.67	20.00	28.72	78.39
	2	*Radermachera hainanensis*	23.08	10.00	25.67	58.75
	3	*Photinia benthamiana*	9.89	5.00	11.00	25.89
	4	*Chukrasia tabularis*	7.69	15.00	2.37	25.06
	5	*Lannea coromandelica*	6.59	10.00	5.35	21.94
	6	*Glochidion wrightii*	4.40	10.00	5.27	19.67
	7	*Suregada glomerulata*	8.79	5.00	5.50	19.29
	8	*Parapyrenaria multisepala*	2.20	5.00	9.78	16.98
	9	*Euodia lepta*	3.30	5.00	2.06	10.36
	10	*Glochidion dasyphyllum*	2.20	5.00	2.44	9.64
	11	*Radermachera frondosa*	1.10	5.00	1.22	7.32
	12	*Sindora glabra*	1.10	5.00	0.61	6.71
Community 4: *Lithocarpus pseudovestitus*	1	*Lithocarpus pseudovestitus*	19.63	5.66	23.38	48.67
	2	*Sterculia lanceolata*	8.59	5.66	6.25	20.50
	3	*Sapium discolor*	8.59	3.77	5.27	17.63
	4	*Canarium album*	3.68	3.77	6.71	14.16
	5	*Memecylon ligustrifolium*	4.29	1.89	7.58	13.76

(continued)

Community	No.	Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance value (%)
	6	*Glochidion dasyphyllum*	4.29	3.77	4.42	12.48
	7	*Sindora glabra*	4.29	5.66	1.16	11.12
	8	*Suregada glomerulata*	3.07	3.77	3.89	10.73
	9	*Glochidion wrightii*	2.45	3.77	3.90	10.13
	10	*Ormosia pinnata*	3.68	5.66	0.64	9.98
	11	*Psychotria rubra*	3.68	5.66	0.55	9.89
	12	*Commersonia bartramia*	3.68	3.77	2.06	9.51
	13	*Garcinia oblongifolia*	0.61	1.89	6.77	9.27
	14	*Sarcosperma laurinum*	2.45	1.89	4.55	8.89
	15	*Wrightia pubescens*	1.84	3.77	3.20	8.81
	16	*Glochidion puberum*	3.07	3.77	1.44	8.28
	17	*Dolichandrone cauda-felina*	1.84	1.89	2.85	6.58
	18	*Ficus microcarpa*	1.84	3.77	0.97	6.58
	19	*Lannea coromandelica*	2.45	1.89	1.69	6.03
	20	*Engelhardtia roxburghiana*	1.84	3.77	0.32	5.94
	21	*Cinnamomum parthenoxylon*	1.23	3.77	0.53	5.53
	22	*Alangium chinense*	1.23	1.89	2.41	5.52
	23	*Symplocos laurina*	1.23	1.89	2.41	5.52
	24	*Euodia lepta*	1.23	1.89	1.90	5.02
	25	*Elaeocarpus petiolatus*	2.45	1.89	0.42	4.76
	26	*Evodla meliaefolia*	0.61	1.89	1.69	4.19
	27	*Radermachera hainanensis*	1.23	1.89	1.02	4.14
	28	*Amesidodendron chinense*	1.84	1.89	0.07	3.80
	29	*Pterospermum heterophyllum*	0.61	1.89	1.08	3.58
	30	*Artocarpus lingnanensis*	1.23	1.89	0.08	3.19
	31	*Chukrasia tabularis*	0.61	1.89	0.66	3.16
	32	*Cryptocarya densiflora*	0.61	1.89	0.15	2.65

9.2.2 Community structure

The community of secondary forest had the simple structure and the canopy density was 1.0. Compared to degraded primary forests, structure of secondary forest communities was less significantly differentiated and only community *Aporosa chinensis* and community *Trema tomentosa* had obvious arbor storey and shrub storey. On the whole, communities of secondary forest had arbor species such as *Aporosa chinensis*, *Lithocarpus corneus*, *Liquidambar formosana*, *Artocarpus tonkinensis*, *Trema tomentosa*, *Radermachera hainanensis*, *Lithocarpus pseudovestitus* and *Sterculia lanceolata*, as well as *Helicteres hirsute*, *Glochidion dasyphyllum*, *Dolichandrone cauda-felina*, *Glochidion wrightii*, *Psychotria rubra*, *Cratoxylum*, *Cochinchinense* and other shrub species. Grass storey had rich species and the coverage was 100%. There are *Aporosa chinensis*, *Euodia lepta*, *Psychotria rubra*, *Trema tomentosa*, *Ormosia pinnata*, *Diospyros strigosa*, *Flacourtia indica*, *Acronychia oligophlebia*, *Arytera littoralis*, *Wrightia pubescens*, *Phoebe henryi* and other tress seedlings, and herbaceous plants such as *Chrysopogon aciculatus*, *Kyllinga brevifolia* etc. In addition, the community of secondary forest has rich vines, such as *Smilax china*, *Papilionaceae*, *Pueraria lobata* and *Abrus mollis*. Thus communities of secondary forest still have valuable tree saplings and seedlings.

9.2.3 Species diversity of arbor storey

As shown in Table 9.6, there are significant differencesin species diversity of arbor storey among different communities of secondary forest in the demonstration area. Species Richness (R) of secondary forest communities were 25, 6, 24 and 32 respectively. Diversity index (SW) were 3.79, 1.19, 2.94 and 4.41 respectively. The Evenness (E) of communities were 0.82, 0.46, 0.82 and 0.88 while Ecological Dominance (ED) were 0.12, 1.00, 0.16 and 0.07respectively. Compared to degraded primary forest, secondary forest showed much lower species richness and higher ecological dominance.

Table 9.6 ***Characters of secondary forests***

Factors	Community 1	Community 2	Community 3	Community 4
Species Richness (R)	25	6	24	32
Diversity index (SW)	3.79	1.19	2.94	4.41
Evenness (E)	0.82	0.46	0.82	0.88
Ecological Dominance (ED)	0.12	1.00	0.16	0.07
Average (DBH)/cm	6.44	4.48	—	—
Average Height(H/m)	5.23	4.74	—	—
Average Density (N)/N · hm^{-2}	5,850	6,600	6,828	8,300
Average Volume (V)/m^3 · hm^{-2}	10.12	26.09	—	—

Note: DBH of trees in *Symplocos laurina* community and *Lithocarpus pseudovestitus* community were not inventoried.

9.2.4 Stand growth

Stand growth of secondary forest was shown in Table 9.6. The average DBH of arbor storey of community *Aporosa chinensis* and community *Trema tomentosa* were 6.44 cm and 4.48 cm while the average height were 5.23 m and 4.74 m respectively. The average volume were 10.12 m^3/ha and 26.09 m^3/ha, significantly lower than that of degraded primary forest. The stand density of 4 secondary forest communities was between 5,850—8,300 N/ha, higher than that of degraded primary forest.

9.2.5 DBH distribution

The DBH distribution of secondary forest in demonstration area was described by analysis of DBH distribution of community *Aporosa chinensis* and community *Trema tomentosa* (see Figure 9.2). The DBH distribution range of secondary forests was 2 – 16 cm, showing the inverse J shape and the maximum diameter was 15.80 cm.

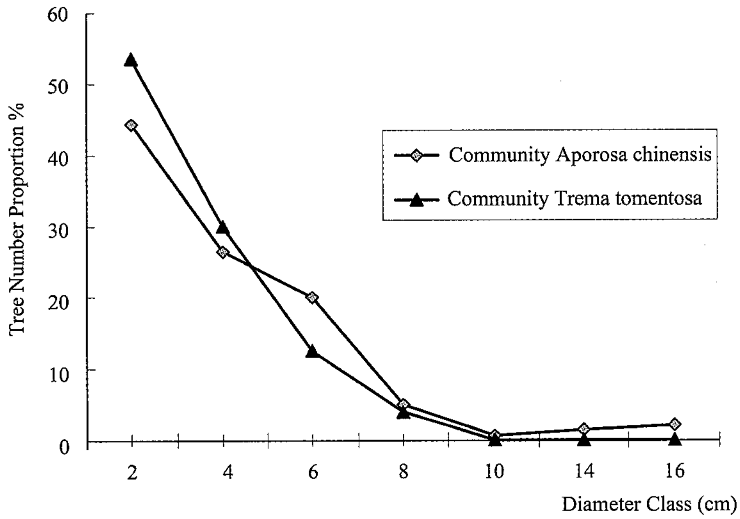

Figure 9.2 *The DHB distribution ofsecondary forests*

9.3 Characteristics of degraded forest land

One community of degraded forest land in the demonstration area was inventoried in March, 2009. A strip plot was set up with an area of 360 m^2 composed of 10 quadrats (6 m × 6 m) for the community. Tree species and height in each quadrat were measured and the results showed that there were few arbor species and shrub species in degraded forest land (see Table 9.7) and the heights were between 0.5 m and 2 m.

Table 9.7 ***Tree species in degraded lands***

No.	Species	Remarks	No.	Species	Remarks
1	*Aporosa chinensis*	arbor species	13	*Antirhea chinensis*	shrub species
2	*Sterculia lanceolata*	arbor species	14	*Smilax corbularia*	shrub species
3	*Bridelia monoica*	arbor species	15	*Micromelum falcatum*	shrub species
4	*Flacourtia indica*	arbor species	16	*Licuala spinosa*	shrub species
5	*Ficus virens*	arbor species	17	*Gonocaryum lobbianum*	arbor species
6	*Sterculia hainanensis*	arbor species	18	*Microcos paniculata*	arbor species
7	*Arytera littoralis*	arbor species	19	*Diospyros strigosa*	arbor species
8	*Randia sinensis*	shrub species	20	*Cratoxylum. cochinchinense*	arbor species
9	*Ervatamia hainanensis*	shrub species	21	*Macaranga hemsleyana*	arbor species
10	*Croton laui*	shrub species	22	*Caryota mitis*	arbor species
11	*Randia depauperata*	shrub species	23	*Salacia hainanensis*	vine species
12	*Acronychia pedunculata*	shrub species		—	

9.4 Site level restoration strategies

9.4.1 Restoration of degraded primary forest

Degraded primary forest in Dagan demonstration area was formed from repeated use of primary forest, mainly at the peak of hills in the southern and southeastern areas. Analysis of characteristics showed that Degraded primary forests still retain the main characteristics of the original forest, such as species composition, soil structure and stand structure, capacity of natural regeneration, and an important function of ecological protection, so a basic management principle of forest restoration is to remove the causes for further disturbance and degradation, and promote restoration through natural succession.

It is the key to identify the forest stands or sites to be protected, which should have seed, wildlings or seed sources in neighborhood to ensure the success of natural restoration. The community of degraded primary forest had a stratified uneven-age structure, composed by arbor storey, shrub storey and grass storey, and the canopy density was is 1.0. There are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* in arbor storey. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings, such species as *Dalbergia odorifera*, *Sarcosperma laurinum*, *Ormosia pinnata*, *Lithocarpus elmerrillii*, *Dolichandrone cauda-felina*, *Cryptocarya densiflora*, *Engelhardtia roxburghiana* and other tree species, *Ervatamia officinalis*, *Aporosa chinensis* and other shrub species, as well as *Indocalamus latifolius* and *Chrysopogon aciculatus*. Therefore, degraded primary forest has the capability of natural regeneration and this type of forest can be restored as managed primary forest, even converted to primary forest by protecting the site from further disturbance or stress factors such as deforestation, over harvesting of timber and non-timber forest products, slash and burn, etc. to restore biodiversity, structure, function and productivity of ecosystem by allowing natural regeneration and succession. This strategy is sometimes called "passive restoration" (Grieser J A, 1997) and is particularly suited to situations where the financial resources for FLR activities are limited. This strategy is probably one of the interventions with low cost and can be extended in many areas. Another measure to promote the protection of degraded primary forest is to plant live fence. Planting *Acacia mangium*, *Eucalyptus* and other fast-growing species as live fence in the boundary among planted forest, degraded forest land and agricultural land can protect degraded primary forest from further human disturbance.

9.4.2 Management of secondary forest

There are two types of ownerships of secondary forest in Dagan demonstration area: one is collective ownership with which the forest was originated from clear-cutting of degraded primary forest, and the other is individual ownership with which the forest was regenerated through a natural process after more than 10 years' abandonment. Forest stands with different ownerships should balance different conflicts and should be restored using different interventions.

Collective owned secondary forest, such as community *Symplocos laurina- Radermachera hainanensis* and community *Lithocarpus pseudovestitus*, its arbor storey has valuable native trees such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, etc. So this type of secondary forest should take the same forest restoration measures as that of degraded primary forest, protective "decompression", that is to achieve natural recovery with use of existing saplings, seedlings by establishing live fence and avoiding human disturbances as much as possible. Individual owned secondary forest, such as community *Aporosa chinensis* and community *Trema tomentosa*, having important timber production species such as *Trema tomentosa* and species like *Dolichandrone cauda-felina* which can be used for afforestation, but lack of valuable native species, should take management strategies of protection and enrichment planting to improve ecological integrity and community benefits by using existing tree seedlings and saplings for protective restoration, together with planting of valuable native species to restore forest communities with trees of high commercial values.

Species selection is the basis for forest restoration. It is crucial to select species of economic, ecological or social interest for the success of enrichment planting. Selecting species to be planted needs to consult local villagers. Ranking of favorite tree species was defined by the process of public participation: *Dalbergia odorifera*, *Aquilaria sinensis* and *Acacia mangium*, etc. So *Dalbergia odorifera* and *Aquilaria sinensis* were selected as species to be planted in the demonstration area because they are valuable native species. The two most common enrichment planting options are line plantings and gap plantings. The choice of method depends primarily on the condition of the forest stand, the restoration objective and the species used. The gap planting method is generally recommended in degraded, over-logged forests while line planting is more suitable if the surrounding trees in the stand are small (less than 10 cm diameter at breast height).

The biggest conflict for restoration of collective owned forest is to avoid the disturbances caused by plantation expanding. Individual family could not be negotiatedfor the implementation of restoration interventions, e. g. the species selection, but should be made understanding of the ecological function of this type of forest and thereby abide by the "logging ban" requirement. The biggest conflict for restoration of individual owned secondary forest is to protect or develop this type of forest to planted economic forest. Local villagers are the decision makers for this conflict, which means the secondary forest is facing human interventions of converting to other uses all the time. Therefore, forest owners should be consulted about specific restoration activities such as tree species selection. It is a principle to select acceptable native species to balance economic benefit and ecological services, that is to meet the "double filter" condition of FLR.

In order to reflect diversity of secondary forest management, collective owned forest has no specific conflict stakeholders so that this type of forest should be managed for providing environment services and forest products only used for firewood. Individual owned secondary forest has conflict of economic benefit and ecological services during restoration process so that this type of forest could be managed with preference to economic benefits, restoring ecological integrity and enhance income of villagers at the same time.

9.4.3 Rehabilitation of degrade forest land

The rehabilitation for degraded forest land focused primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Analysis of characteristics showed that the degraded forest land had better soil condition, but had few trees seedlings and saplings. Afforestation is the main rehabilitation strategy because restoration relying on protection will take a long time. As degraded forest land with characteristics of low soil fertility and poor soil structure, soil erosion and subjected to frequent human disturbance, restoration activities are better focused on the recovery and maintenance of primary processes. First select pioneer trees as nurse crop, important silvicutrual characteristics for species suitable for nurse crop include fast-growing, tolerance to drought and diseases, if necessary, select exotic species, such as *Eucalyptus*, *Acacia mangium*, etc. Then valuable native species are planted understory, such as *Dalbergia odorifera*, *Aquilaria sinensis* . Forest will be logged in a few years to increase the light intensity needed by native species. In this way, both rehabilitation of degraded forest ecosystem and income of local villagers will be improved.

10 Application of PRA

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used in the FLR planning of the county.

FLR makes use of collaborative approaches to harmonize the many land-use decisions of stakeholders with the aims of restoring ecological integrity and enhancing the development of local communities and national economies. Implied in the word "process" are three key principles: (1) it is participatory; (2) it is based on adaptive management and thus responsive to social, economic and environmental change; and (3) it requires a clear and consistent evaluation and learning framework. "Participatory" continues throughout the life of the initiative, from the data collection, landscape dynamics and driving forces analysis to identifying priority sites. As one of the important differences between FLR and many other restoration-oriented technical responses, meaningful public participation is the basis and prerequisite of implementing FLR and the key for the successful implementation of forest landscape restoration.

Taking Dagan FLR demonstration area as a case, this chapter studied the application of PRA methods in FLR initiative through the use of the PRA tools, combined with community-level FLR planning and implementation process.

10.1 Using PRA tools

FLR initiatives at community level is a process that stakeholders in the community analyze the problems in forest landscapes and make FLR plan together so as to restore the community ecological integrity and improve the human well-being of the residents.

PRA tools such as Direct Observation, Community Workshop, Semi-structured Interview, Group Discussion (the poor, the women, etc.), Participatory Mapping, Seasonal Calendar, Matrix and Ranking, and Problem Tree were used here and this chapter focuses primarily on the use of Community Workshop, Field Survey, Participatory Forest Inventory, Semi-structured Interview, and Matrix and Ranking in the community FLR.

10.1.1 Community workshop

Community workshops were held in Dagan FLR demonstration area in May 2008, March 2009 and May 2009 respectively. The main purpose of the first community workshop was to make the villagers understand FLR initiative, encourage their active participation and to identify the key difficulties and the solution that villagers think in the current community development. The first community workshop was held on May 14, 2008 with the helpfrom Qunying Town leaders and there were totally 171 participants (at least one person per family), including 68 women. The following items were presented to villagers: (1) introduction to purpose, background and content of FLR initiative at community level; (2) introduction of the FLR work group; (3) description of the purpose, task and activity arrangement of FLR work group; (4) How to collaborate and participate for villagers; (5) help villagers to elect village representatives to implement FLR initiative. The second village workshop were held in March 24, 2009 after field survey and participatory forest inventory (Subcompartment division and subcompartment cruise), aiming at verifying the boundaries and ownership (householder) of subcompartments and getting feedback of FLR draft planning from villagers to correct the plan timely. As the priority sites need to be identified in this meeting, most sites are collectively owned degraded primary forest and secondary forest, there were totally 421 participants, including 156 women, meeting the request of 2/3 of the villagers to participate in the meeting. The village workshop were held in 3 villages respectively because of the large number of participants. Problems, causes and solutions in Dagan FLR demonstration area, ranking of favorite tree species, verifying maps of landscape mosaic, and identifying the ownership of priority sites were presented in the meeting. The third village workshop was held in May 26, 2009 before implement site level restoration measures and aimed at getting the feedback of site level restoration interventions, passing community FLR Plan by vote and signing contracts related to implementing restoration measures. There were 154 villagers participated in the meeting, at least one person per family, including 53 women.

10.1.2 Field survey

Based on topographic maps, cadastral maps and interpreted RS images, land-use, ownership, management history and the future land use of each patch was identified through field visits, direct observation and villagers' interview. Field survey was conducted during November, December 2008 and March, April 2009, aiming at identifying the patch boundaries with different ownerships or different landscape element types. The following steps were included in the field survey: (1) to find acquainted informants who are willing to cooperate, such as the leaders of village groups, the former Ranger, etc.; (2) to identify survey route after discussions with key informants; (3) to conduct survey and to communicate, discuss with villagers; (4) to draw the patch boundaries together with key informants and to indicate the specific information of each patch combined with villager interviews; (5) to check the patch boundaries and to draw maps of landscape mosaic in different periods.

10.1.3 Participatory forest inventory

Subcompartment division and subcompartment inventory were conducted in Dagan FLR demonstration area. Community characteristics and forest measuration characteristics of degraded primary forest and secondary forest in demonstration area were also inventoried. Investigators should include at least one key informants (or village representatives), so as to take advantage of local knowledge and help the villagers understand the importance of biodiversity conservation and sustainable use of existing forest resources, thereby assisting villagers to analyze the problems and possible countermeasures of current forest management activities. Experience shows that local residents are very concerned about how to use forest to maintain and improve their daily lives, and the ability, security to benefit fromthe use of forest resources. There is no conflict on the use of forest in community because of local rules and regulations. The main conflicts on forest resources are between government and community, as well as forest users of different communities.

10.1.4 Semi-structured interview

Individual farmers were interviewed on the topic of forest degradation and restoration based on the problems found in field survey and forest inventory by means of semi-structured interview. This tool were used in four parts: determination of patch boundaries and ownerships, analysis of the driving forces of landscape changes, analysis of problems and solutions of forest management, and consultations of restoration measures for priority sites. Semi-structured interview was also important tool for collecting socio-economic conditions of residents.

10. 1. 5 Matrix and ranking

Enough information and a lot of problems have beenobtained from village workshops, forest inventories, semi-structured interviews, group discussions, participatory mapping and other steps. The intrinsic relationship and possible results were found by classification and analysis the information and materials collected. Then the problems were ranked and strategies and methods were analyzed preliminarily. Different people have different views on the same thing because of differences on preferences, knowledge, and experience. The purpose of matrix and ranking was to collect the different perspectives on tree species selection, problems and development planning of community and other issues so as to make decisions representing the majority. Matrix and ranking was mainly used during village workshops.

10. 2 Results analysis

10. 2. 1 Natural resources

Dagan FLR demonstration area is located in the Qunying township, with the area of 399. 48 ha. Landforms of the areas are mostly low mountains, hills, with a landform pattern of lowering down from South to North, and from East and West to the Centralwith an elevation of 30 – 340 m. Species diversity of the region is rich. Major soil is brown-yellow soil. The site is suited for the growth of variable tropical cash crops because of full rainfall, good light and temperature conditions and suitable climate. There are totally 5 reservoirs and one stream throughout the village, providing irrigation water for agriculture and forestry development. Forest resources were rich twenty years ago. The natural forest has reduced sharply due to deforestation, slash and burn and conversion to rubber plantations. Intact degraded primary forest and secondary forest can only be found in the hill peaks and remote areas not accessible by human activities while areas in the foot of hills, close to human settlements and with access to water were replaced by rubber trees, cassava, litchi, and mango plantation.

There are 89. 61 ha natural forests and 240. 30 ha plantation now in the demonstration area. The areas of degraded primary forest and secondary forest were 42. 06 ha and 47. 55 ha respectively. There are many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* in degraded primary forest communities. Secondary forest communities have also some valuable native species in Hainan Province, such as *Chukrasia tabularis* and *Amesidodendron chinense* (with first class wood), timber production species such as *Ormosia pinnata*, *Lannea coromandelica* and *Garcinia oblongifolia*, and important species for commercial forest in Hainan Province, such as *Trema tomentosa*, as well as afforestation species like *Dolichandrone cauda-felina*, etc. Species used for plantation are *Areca catechu*, rubber tree, *Eucalyptus*, with the area of 166. 36 ha, 45. 86 ha and 10. 02 ha respectively. The area of plantation less than 5 years old is 151. 70 ha while those more than 5 years old is 57. 70 ha.

Natural forest has diverse non-timer products, medicinal plant such as *Bridelia tomentosa*, *Sapium discolor* and *Pueraria lobata* can be used for microbial resistance, *Millettia speciosa* can be used for treatment of nervous system diseases and enhancement of immune function, *Sterculia lanceolata*, *Papilionaceae* can be used for treatment of bruises, fruits such as longan, *Cleistocalyx conspersipunctattum* and *Canthiun horridum*, aromatic plant such as *Chukrasia tabularis*, as well as ornamental plant *Caryota ochlandra* .

10. 2. 2 Socio-economic aspects

Dagan FLR demonstration area, including three villages (Dagan, Fenyou and Fenjie) is a typical minority nationality habitat, belonging to the Li minority area, economic development lags behind the county average, The total number of families in the demonstration area is 134 in 2009 with a total population of 586 (Li nationality), including 348 men and 259 women. There are 64 families, 228 people with 151 labors in Fenyou village, 40 families, and 186 people with 110 labors in Fenjie village while there are 60 families, 224 people with 153 labors in Dagan village. The annual per capita net income is about 110 US $ (see Figure 10. 1). In 2009, there are totally 134 migrant workers, most of which are young people.

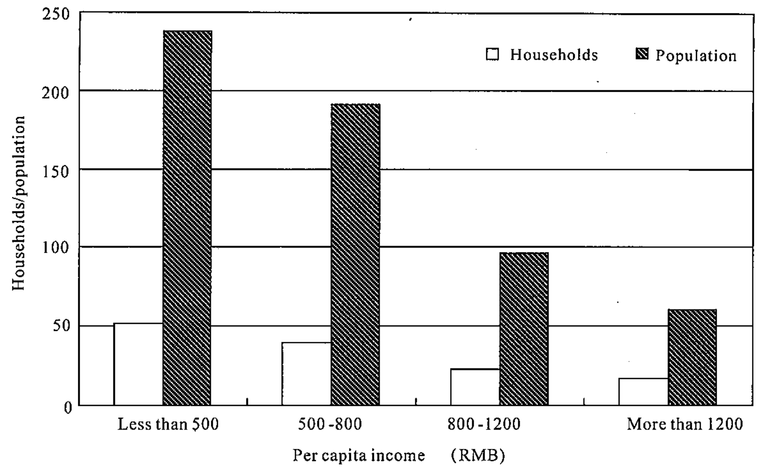

Figure 10. 1 ***Per capita annual income of residents in Dagan FLR demonstration area***

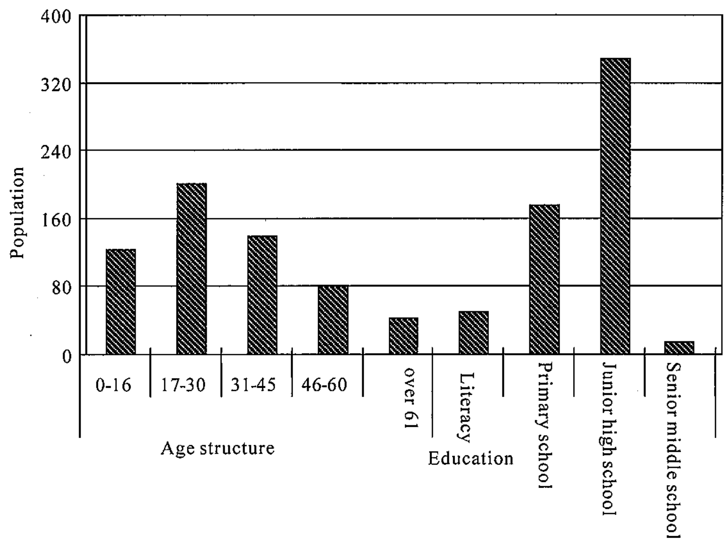

Figure 10. 2 ***Age structure and educational level of residents in Dagan FLR demonstration area***

The main crops are rice, supplemented by corn and sweet potatoes. Rice can be harvested once or twice a year. However, reduction of land cover and land conversion due to sandy soil and caused by human disturbance, such as slash and burn, management and investment, make the soil erosion even severe in rainy season. In addition, pond-deposit caused by soil erosion and combined with uneven seasonal rainfall also makes frequent drought in the area, such as the original fields for autumn rice due to lack of water can not be planted in spring. Rice can plant in June and July even if it is the rainy season. At present, non-paddy field are clearly defined, most are used for cassava cultivation.

The arrangement of agricultural activities in Dagan FLR demonstration area was shown in Table 10. 1.

Table 10. 1 ***Seasonal Calendar of Dagan FLR demonstration area***

Crops	Jan.	Feb.	Mar.	Apr.	May	Jun.
Sweet potato		Planting				
Rubber tree	Weeding	Fertilizing	Weeding	Tapping	Tapping	Tapping
Betel nut				Flowering		
Early rice	Fertilizing		Fertilizeing	Harvesting		
Late rice					Planting	Fertilizeing
Mango	Flowering				Harvesting & Prunning	Weeding
Cassava				Planting		
Corn				Planting		Harvesting
Melon & vegetable		Harvesting	Harvesting			
Crops	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Sweet potato		Harvesting	Harvesting			
Rubber tree	Tapping	Tapping	Tapping	Tapping	Tapping	Fertilizeing
Betel nut				Harvest	Harvest	Fertilizeing
Early rice						Planting
Late rice		Fertilizeing	Harvesingt			
Mango	Fertilizing					
Cassava						Harvesting
Corn	Harvesting					
Melon & vegetable					Planting	Fertilizeing & irrigateing

Dagan FLR demonstration area is impassable in terms of transportation and the only rural road to the county town is in poor condition, providing no benefit to the transportation of agricultural products, technology and information. The road have been constructed in January, 2010 under current policy of stimulating domestic demand. The main transport tool is motorcycle (one per household). The education level of residents is uneven, people under the age of 35 have junior high school education and there are only two in the village who have got college education (see Figure 10. 2).

School-age children go to school in the local town while children in high income families go to school in the county town. There is no professional medical staff in the village and villagers have to go to township health centers, clinic in Nanping farm and hospitals of the county to see a doctor.

As to energy structure, fuelwood is the major energy source and biogasis only used in five families. Sample survey on fuelwood consumption of 60 families has shown that the average daily consumption of fuelwood per household was 28kg, per capita consumption of fuelwood was 5. 5kg (see Figure 10. 3). Firewood are mainly used for daily life, such as cooking, bathing and pig feeding. The survey found that concept of "reflects environment everyday" were deeply rooted in the Dagan FLR demonstration area so that firewood was the natural choice in the community. However, this energy use is more extensive and residents generally use stove with lower energy efficiency. Rice cooker, induction cooker have not been in wide use, only 15 families were using electricity for cooking. Fuelwood were mainly from natural forests surrounding the community, mainly are dead tree- - shrubs. Fuelwood collection on natural forests has caused some damages. The implementation of forest landscape restoration measures will inevitably affect the natural choice. Therefore, coal, gas, electricity and other alternatives should be encouraged in order to reduce the consumption of forest resources. As these alternatives are not conducive to extend because the price of these energy alternatives are higher than that of firewood, the government and relevant government agencies should adopt some poverty reduction polices, such as subsidizing construction costs of methane tank.

10. 2. 3 Ranking of problems

Problems, causes and solutions of Dagan FLR demonstration area were shown in Table 10. 2. It should be noted that all the problems can't be solved in the short term just relying on FLR. FLR aims to restore ecological integrity and human well beings of the community, there would be no problem in the long term if the human well being is improved. The key problems need to be solved in FLR plan in Dagan FLR demonstration area are the difficulties that can be solved in short term by communication and cooperation among different stakeholders, such as problem 1, 2, and 5 listed in Table 10. 2. Other problems can be solved after human well being are improved and community income are enhanced, as the fundamental reason for these problems is poverty and lack of funds.

Table 10. 2 ***Ranking of problems in Dagan FLR demonstration area***

Rank	Problems	Causes	Solutions
1	Poor roads, traffic inconvenience	Poverty, no funds	(1) Government-funded road construction (2) Villagers can put labor (3) Increasing revenue after rubber tapping
2	Lack of irrigation water	Less water in reservoirs, no funds to repair the ditch	(1) Increasing the height of reservoirs by government funds (2) Repairing the ditch by (3) Protecing the reservoirs by tree planting
3	Lack of fertilizer for betel nut and rubber trees	Betel nut and rubber are too young to harvest, low income, Large-scale cultivation, no money to buy fertilizer	(1) Integrited into government poverty reduction policy (2) Cassava planting (3) Raising pigs to get Organic fertilizer (4) Loans to buy fertilizer
4	Lack of housing	Low income	(1) Government grants received (2) Increasing revenue after rubber tapping (3) Saving money by work outside
5	Difficulty of going to toilet and taking a bath for women	Lack of bathrooms	(1) Subsidies for bathroom building by government (2) Methane tank construction (3) Public toilets building by raising funds
6	Powdery mildew	Lack of pesticides and techniques	(1) Guidance by forestry stations (2) Government-issued pesticide (3) Technical training

Poor roads, traffic inconvenience were agreed as the most urgent problem for current village development and the most important solution is government-funded road construction because of high cost and limited funds raised by villagers. As the main infrastructure construction in Dagan FLR demonstration area recently, roads sclerosis is an important part of the community FLR plan. The road construction would be conducted under support from the existing national policy of stimulating domestic demand (The road construction has been finished in January, 2010). Villagers believe that lack of irrigation water is the second major problem and hope to increase thecapacity of reservoirs and con-

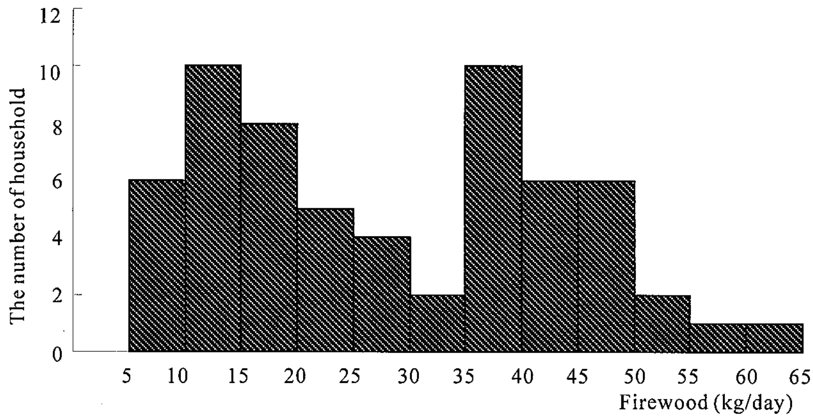

Figure 10. 3 ***Distribution of families of daily firewood consumption in Dagan FLR demonstration area***

struct ditches by government fund. Meanwhile, the villagers have realized the role of natural forest for the protection of the reservoirs. This problem can be solved by incorporating water conservancy facilities into water project planning of the Department Water Resources of the government. Difficulty of going to toilet and taking a bath for women can be solved by the construction of biogas digesters. Materials after fermentation could also provide fertilizers for rubber and betel nut growing.

10. 2. 4 Status and causes of forest degradation

The status and causes of forest degradation in Dagan FLR demonstration area were analyzed using the problem tree method. Problem tree can help outsiders and locals to find and analyze the impact of an event, the flow of resources and activities by expressing the causes, effects and linkages between the causes for the problem so as to find the intrinsic link and key reasons. Reasons for natural forest deforestation, degradation and fragmentation in community were analyzed through PRA tools, such as village workshops, and interviews with farmers, as shown in Figure 10. 4. The areas of degraded primary forest and secondary forest in Dagan village were 42. 06 ha and 47. 55 ha respectively, only distributed in south-eastern part of the community. But the forests were widely distributed 30 years ago, covering almost all the hills. The area of degraded primary forest was still 97. 64 ha in 1990. Degraded primary forest has reduced by 55. 58 ha during the period of 1990 – 2009, which resulted in the forest fragmentation. As shown in the problem tree, the main causes for

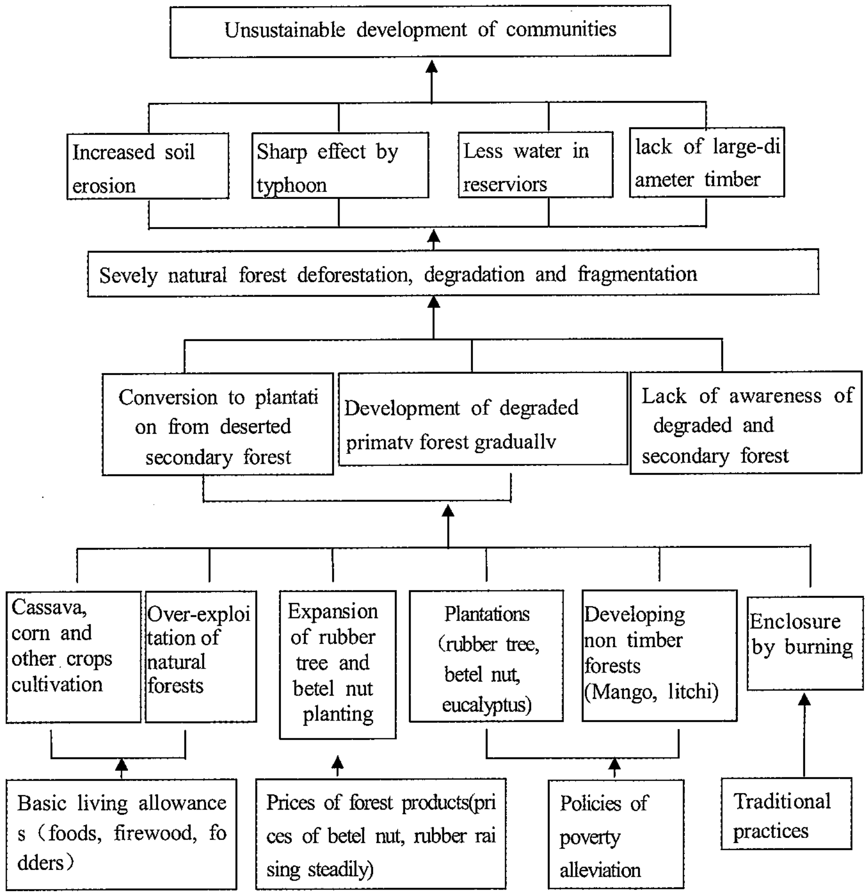

Figure 10. 4 ***Problem tree for causesfor forest degradation in Dagan FLR demonstration area***

natural forest reduction were natural forest deforestation by basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices.

10. 2. 5 Identifying priority sites and tree species

Priority sites and restoration measures, favorite tree species were identified byusing Matrix and Ranking in village workshop (see Table 10. 3 and Table 10. 4). Site-level restoration measures should take advice of local residents and should be implemented by them, and that will contribute to the successful implementation. It should be noted that residents made decisions on restoration measures and planting tree species from their own economic interests, some choices do not meet the double-filters of FLR, for example, *Acacia mangium* was generally agreed as the best windbreak species, but field survey found that most of *Acacia mangium* trees which have been planted along the ridge of hills were break down by typhoon. So conflicts between different restoration measures should be coordinated timely to find the compromise between economic and ecological benefits.

Table 10.3 ***Priority sites and restoration interventions***

Priority sites	Interventions	Reasons
Sites along roads	Planting urban tree species, such as Coconut Tree	beautify the environment, sunshade
Sites along streams	Planting native species	Protecting the ditch, pond
Deraded forest land in flat area	Planting rubber tree instead of Areca catechu	Improving income, enough Areca catechu
Deraded forest land in hill peaks	Planting wind-break trees (Acacia mangium), eucalyptus	Wind-breaking, improving income,
Forest lands	Protection	Wind-breaking, protecing rubber trees

Table 10.4 ***Ranking of favorit tree species***

Species	Advantages	Disadvantages	Rank
Rubber tree	Rubber tapping 5 years later, planting for 50 years	Powdery mildew	1
Eucalyptus	Fast-growing, highsurvival rate	Harvest 5 years later, lack of water	2
Dalbergia odorifera	Valuable	Slow growth	3
Aquilaria sinensis	Valuable, air purification	Slow growth	4
Acacia mangium	Against typhoons, planting around the houses	—	5

10.2.6 Skills for PRA tools application

Not all the tools and methods of PRA will be used during the development of FLR plan at community level. PRA methodscan be enriched and developed according to local conditions. The following items need to be given attention during village workshops: speaking local languages as far as possible and simplify the questions to let all villagers understand; putting the emphasis on introduction in the first community workshop for low participation; using PRA tools in variety of ways after villagers are willing to ask, discuss and share information; guiding the meeting in a positive direction to avoid a few people dominate the meeting; every discussion, analysis should have results or conclusions and should be recorded, feed backing to villagers next meeting so as to correct timely, selecting appropriate meeting time and place, 1-2 hours is suitable.

Experiences in semi-structured interviews in Dagan FLR demonstration area showed as follows. (1) selecting team members, topic design and identifying interview objects should be fully prepared before the interview. Team of semi-structured interview included one translator because there was barrier for FLR team to communicate with local residents. (2) Interview time is critical and should be fixed based on daily work and life of local laws, seasonal farming activities, work habits, climate, local customs, etc. (3) Interviews should be started from family structure (family member, name, age, educational level, etc.), land ownership, crop cultivation, livestock breeding species and the number. It could enable farmers to increase their self-confidence on the one hand. On the other hand, it would help to obtain valuable information from conversation to guide the sub topics. (4) FLR working team should not give villagers hints or promises that they would get any benefits in the future in order to get reasonable and reliable answers. (5) Answers given by villagers should not be exposed and kept private. (6) Taking notes should be agreed by interviewees and don't use tape recorders. (7) The interview time should be kept in one hour, thank the respondents at the end of the interview and ask them if there is any question.

Matrix and ranking can fully reflect the participation of villagers, especially community in rural area. Using symbols that villagers can understand to express the contents of matrix and ranking could motivate villagers' enthusiasm and achieve the survey objective.

Moreover, FLR working team should pay attention to the role of government departments and make full use of indigenous knowledge, especially traditional knowledge of farmers.

11 Conclusions and recommendations

11.1 Conclusions

Taking Lingshui Li Autonomous County and Dagan FLR demonstration area as a case, this study constructed the systematic approach to FLR from the view of regional-level. Key techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies were put forward. The main conclusions are as follows.

11.1.1 The systematic approach to FLR

FLR initiatives should be implemented according to the following steps: analyzing stakeholders, building support for FLR, understanding the landscape mosaic and its dynamics, analyzing driving forces, identifying site-level options and priority sites, developing site-level restoration strategies, making FLR plan, and monitoring and evaluating. Stakeholder approach, balancing land-use trade-offs, joint decision-making and conflict management are the methods involved in the steps. The "double filter", public participation and adaptive management are the principles that must be followed in the whole process. These methods, principles and above steps constitute the systematic approach to FLR.

Stakeholders can be analyzed from characteristics, needs, interests, potentials, degree of participation and other aspects. Building support for FLR is to build the support of stakeholders for FLR initiatives. Forest mosaic and dynamics can be analyzed according to the following steps: landscape elements classification, data collection and processing, landscape pattern analysis, landscape dynamics analysis and prediction, driving forces analysis. Data of Forest Management Inventory, RS image information extraction and sampling inventory are methods for regional level baseline data collection. Community-level data has been obtained by participatory subcompartment division and cruise.

The variety of ecological conditions and diversity of stakeholder views mean it may not be possible to restore forestat all sites in a landscape. However, by strategically targeting areas for various kinds of reforestation, these interventions will collectively improve key ecological processes (e. g. hydrological functions, nutrient cycling etc), restore biodiversity and thereby improve livelihoods across the landscape. Applicable principles for identifying priority restoration sites can be put forward based on ecological and socioeconomic conditions and diversity of stakeholder views. Site level restoration strategies should be developed on the basis of analysis of characteristics of degraded and secondary forests combined with participatory survey, including restoration of degraded primary forest, management of secondary forest, rehabilitation of degraded forest land and restoring forest functions of agriculture lands. Forest landscape restoration planning is to arrange restoration interventions for priority sites from the perspectives of time and space and to implement the planning relying on stakeholders. Monitoring & Evaluation is the basis and foundation of adaptive management in FLR and the key is to establish a set of indictors to evaluate the context and implementation of FLR.

11. 1. 2 Landscape pattern at region level

In view of forest restoration and rehabilitation, system of forest landscape element types of Lingshui County was set up, including primary forest, degraded primary forest, secondary forest, degraded forest land, rubber plantation, *Casuarina equisetifolia* Plantation, trees around villages, other plantations, other forest lands, residential quarters land, garden plots, agricultural land and other lands. RS data in three yeas (in 1991, 1999 and 2008) are the source of baseline information in landscape pattern analysis of Lingshui Li Autonomous County. Landscape pattern and dynamics of the study area were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The results showed that the area proportions ofPrimary Forest, Degraded Primary Forest and Secondary Forest were 4. 74%, 6. 29% and 22. 80% respectively. During the period of 1991 to 2008, primary forest has been kept stable. The areas of Degraded Primary Forest and Secondary Forest have decreased while Patch Density (PD) and Edge Density (ED) have increased, indicating the patch shape tended to be more complex and thereby they become more fragmented.

11.1.3 Landscape pattern at community level

System of forest landscape element types for landscape pattern analysis at community level was set up, includingDegraded Primary Forest, Secondary Forest, Degraded Forest Land, Plantation, Non-paddy Cropland, Paddy Field, Human Settlement, Reservoir or Pond. Based on RS information extraction, participatory subcompartment division and inventory were used to obtain 3 maps of landscape mosaic (in 1990, 1999 and 2009) of Dagan demonstration area. Landscape pattern and dynamics were analyzed with landscape indices method and Markov model was established to forecast its development tendency.

The results showed that the demonstration area was a heterogeneous forest landscape in whichPlantation was the matrix (accounting for 60.15% of the total area) and other types was scattered among the matrix in 2009. The area proportions of Secondary Forest and Degraded Primary Forest were 11.90% and 10.53% respectively. Overall, Non-paddy Field and Degraded Primary Forest were the matrix of the demonstration area in 1990, and then with the reduction of Degraded Primary Forest and Secondary Forest and the increase of Plantation, Non-paddy Field and Degraded Primary Forest had become the main types in the landscape resulting in a high heterogeneous landscape in 1999, and in 2009 the landscape pattern has become that Plantation was the dominant type and other types was scattered among the Plantation during the period of 1990 - 2009. Prediction of landscape dynamics showed that degraded primary forest would reduce sharply while secondary forest, degraded forest land and plantation would increase slightly, therefore resulting in the decrease of landscape heterogeneity.

11.1.4 Driving forces of landscape dynamics

Driving forces of forest landscape dynamics can be analyzed preliminary by transition probability matrix constructed by Markov model. Transition probability matrix and participatory survey method can be used to study the factors for forest landscape dynamics both at region level and community level.

The results showed that forestry policies and key programs were the dominant factors which cause the increase of forest quantity and quality during the period of 1991 to2008 in Lingshui Li Autonomous County. Reducing rural poverty through development is an important factors in the changes on forest landscape in western hills area and northern middle hills region. Livelihood development was important factor in the changes on forest landscape in the whole hills area and middle hills region. Village greening and farm-shelterbelt forest were important factors in the changes of forest landscape in central plain terrain. Sand excavation, pond fishery and tourism development are important driving forces for changes in forest landscape in coastal area.

Forest landscape dynamics during 1990 to 2009 in Dagan FLR demonstration area was the joint results caused by several driving forces, such as the basic living allowances, policies of poverty alleviation, prices of forest products and traditional practices. In order to solve the problem of food and cloth shortages, local residents developed degraded primary forest and secondary forest into cassava fields in the 1990s, especially during the period of 1990 – 1999. Policies of poverty alleviation and prices of forest products caused the conversion to plantation from degraded primary forest and agricultural land, which resulted in the sharp expansion of rubber tree plantation, betel nuts tree plantation, etc.

11.1.5 Characteristics and restoration strategies of degraded and secondary forests

Analysis of characteristics of degraded and secondary forest in Dagan demonstration area showed that degraded primary forest hasan integral community structure. Most valuable trees in the sub-storey I in arbor storey have been harvest while there were many valuable native trees with better stem form such as *Dalbergia odorifera*, *Hopea exalata*, *Vatica mangachapoi* and *Litchi chinensis* because of the disturbances such as repeated selective cutting. Shrub storey and grass storey in forest stands have rich species and valuable tree saplings and seedlings. Compared to degraded primary forest, secondary forest has simple community structure and low diversity, but with valuable native trees and timber species in arbor storey.

Site-level restoration strategies: degraded primary forest in Dagan FLR demonstration area was formed from repeated use of primary forest. The basic restoration strategy for degraded primary forestis to protect the site from further disturbance or stress factors such as deforestation, over harvesting of timber and non-timber forest products, slash and burn, and to restore biodiversity, structure, function and productivity of ecosystem by allowing natural regeneration and succession. Protection and enrichment planting are the management strategies for secondary forest. Protective "decompression" is the main strategy for collective-owned secondary forest while enrichment planting combined with protection is the suitable strategy for individual-owned secondary forest. Species for enrichment planting should be valuable native trees, such as *Dalbergia odorifera*, *Hopea exalata*. The rehabilitation strategy for degraded forest land focuses primarily on tree-planting. Meanwhile, residual tree seedlings should be protected as much as possible. Planting live green fence is one of the effective measures for protection of degraded and secondary forests.

11.2 Recommendations

The FLR concept is still being refined and redefined, involving knowledge of multiple disciplines, such as landscape ecology, restoration ecology, stakeholder theory, public participation mechanisms, adaptive management and forest management. This book studied the systematic approach of FLR, and key techniques in pattern analysis of forest landscape, analysis on driving forces of forest landscape dynamics, degraded and secondary forest characteristics and site-level restoration strategies, but the following areas need to be studied in the future.

Techniques of FLR As to Monitoring & evaluation, indicator system needs to be rich and refined and thereby used to study the monitoring and evaluation of FLR. In terms of site-level restoration strategies, site-level strategies for plantation management and the function of plantation in FLR need to be studied further.

Conflict and balance between restoring ecological integrity and enhancing human well-beings The double-filter principle states that the trade-offs between the economic interests and social, protective values is unavoidable, but the landscape-level sum of all site-level actions should attempt to balance the economic, social and environmental benefits, that is to balance the two objectives of enhancing human well-being and restoring ecological integrity. There is prominent conflict between restoring ecological integrity and improving human well-being in forest-dependent poor communities. Multifunction of landscape has not emerged, especially the economic benefits, so developing alternative industries become the effective measures to improve income of local inhabitants. For example, alternative industries including breeding in forest, beekeeping, off-season vegetables growing, etc. can be developed in Dagan FLR demonstration area during the implementation of FLR initiatives. However, development of alternative industries and community capacity-building require the resources superiority of surrounding communities and the region. Therefore, it needs to study further for balancing the conflict between restoring ecological integrity and improving human well-being in poor communities within the development of community.

Incentive mechanism Degraded and secondary forest can be classified into two categories according to forest function: production forest and protection forest. Degraded and secondary production forests are widely distributed in surrounding areas of forest-dependent communities and play an important part in community development. While degraded and secondary protection forests are in well protection and restoration because of implementing the Scheme of Forest Ecological Benefit Compensation Fund for Non-commercial Forests, the degraded and secondary production forests are gradually converted to crop-trees and degrading in most forest-dependent communities mainly due to lack of PES (Payment for Ecosystem Services) scheme. So study on scheme of payment for environment services derived from degraded and secondary production forests can help improve the incentive mechanism for FLR and thereby promoting the successful implementation of FLR.

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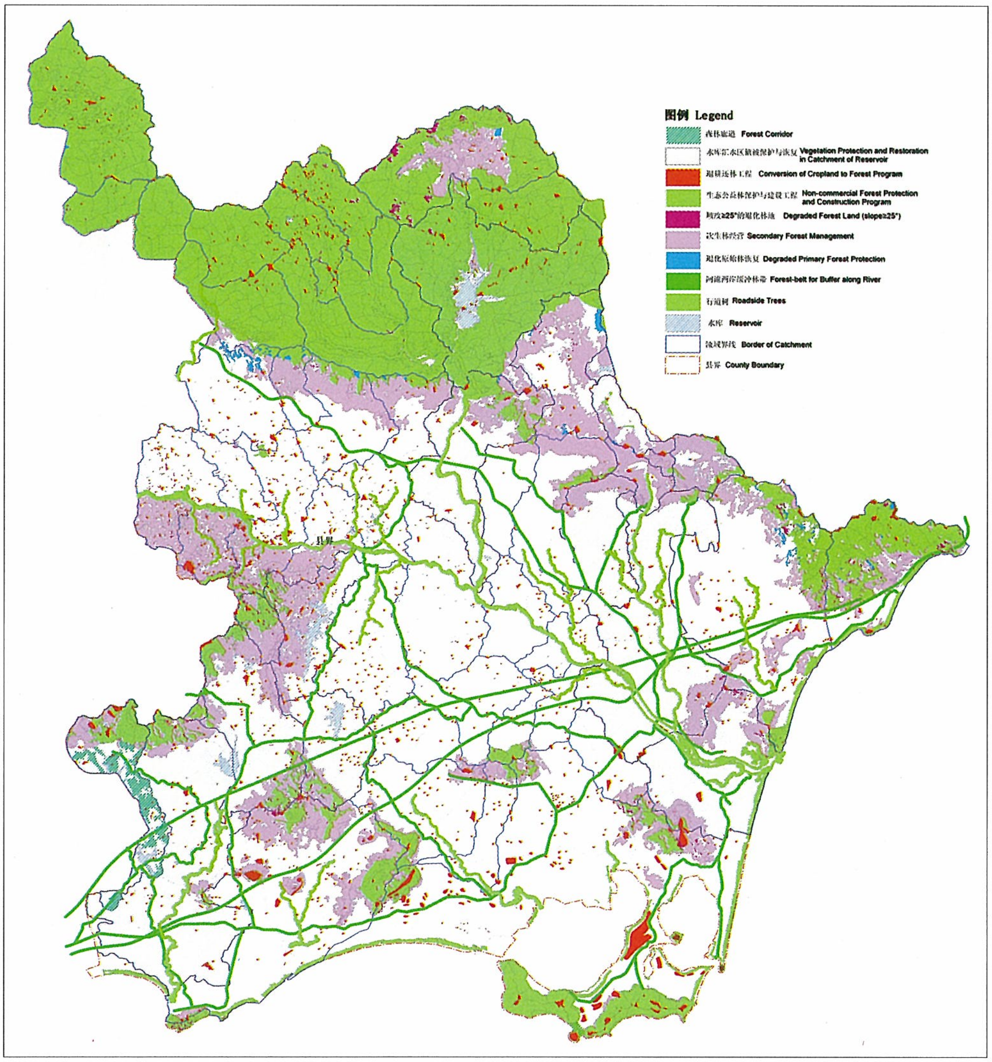
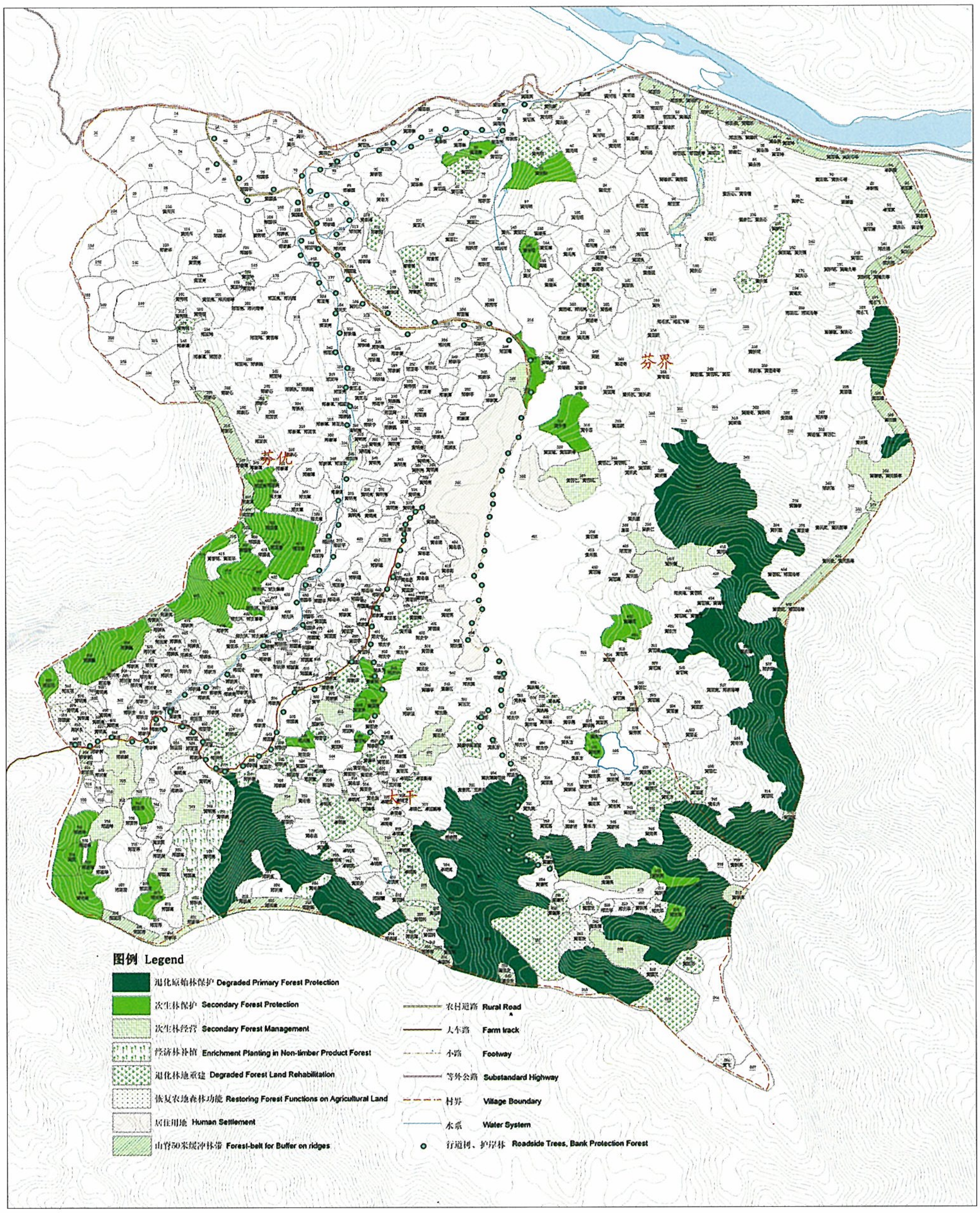
附录 1　陵水黎族自治县 FLR 规划图
Annex 1　Map of FLR plan (priority sites) of Lingshui Li Autonomous County



附录 2 大敢 FLR 示范区优先恢复立地图
Annex 2 Map of priority sites of Dagan FLR demonstration area



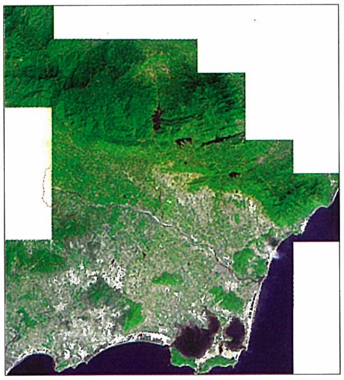
附录 3　陵水黎族自治县 1991 ～ 2008 年多期遥感影像

Annex 3　RS images of Lingshui Li Autonomous County

1991 年 LANDSAT—TM 影像
LANDSAT-TM image in 1991

1999 年 LANDSAT—ETM 影像
LANDSAT-TM image in 1999

1999 年航片　Aero photo in 1999



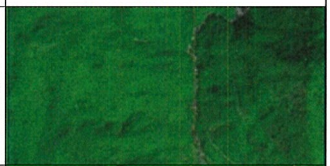
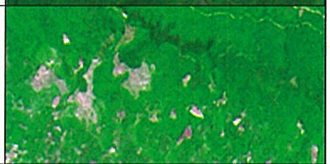
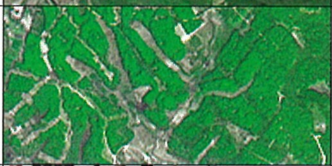
2006 年 SPOT5 影像　SPOT5 image in 2006

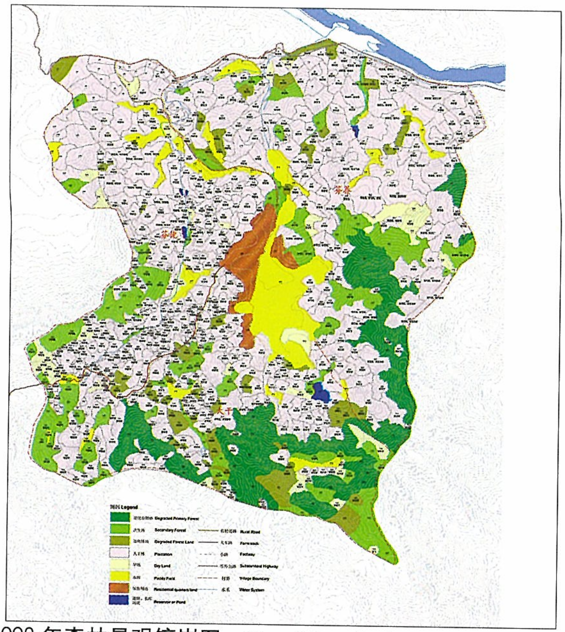
2007 年 ALOS 影像　ALOS image in 2007

2008 年 SPOT2 影像　SPOT2 image in 2008

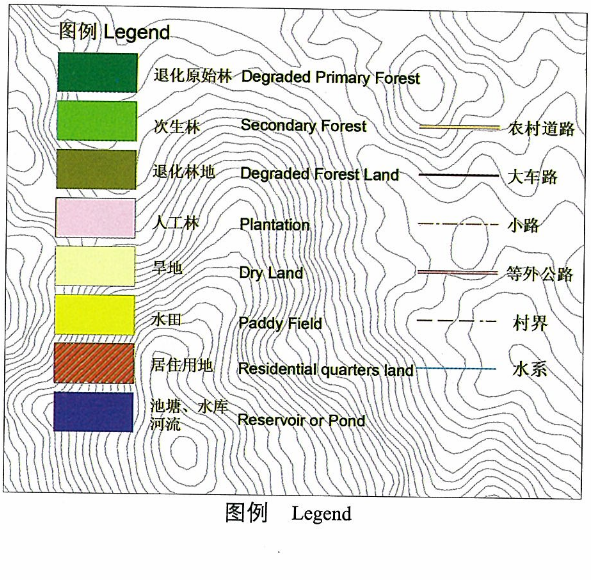
附录 4 陵水黎族自治县不同景观要素类型遥感典型影像

Annex 4 Typical RS images of landscape element types in Lingshui Li Autonomous County

<table>
<tr><th>类型 Type</th><th>遥感典型影像 Typical image</th><th colspan="2">类型 Type</th><th>遥感典型影像 Typical image</th></tr>
<tr><td>原始林
Primary Forest</td><td></td><td colspan="2">退化原始林
Degraded Primary Forest</td><td></td></tr>
<tr><td>次生林
Secondary Forest</td><td></td><td colspan="2">退化林地
Degraded Forest Land</td><td></td></tr>
<tr><td>橡胶林
Rubber Plantation</td><td></td><td colspan="2">村旁树
Trees around Villages</td><td></td></tr>
<tr><td>木麻黄人工林
Casuarina equisetifolia Plantation</td><td></td><td colspan="2">其他人工林
Other Plantation</td><td></td></tr>
<tr><td>其他林地
Other ForestLand</td><td></td><td rowspan="4">其他用地
Other Land</td><td>河流
River</td><td></td></tr>
<tr><td>居住用地
Residential Quarters Land</td><td></td><td>沙地
Sandy Land</td><td></td></tr>
<tr><td>园地
Garden Plots</td><td></td><td>沙滩
Sand Beach</td><td></td></tr>
<tr><td>农用地
Agricultural Land</td><td></td><td>水库、湖泊
reservoir or Lake</td><td></td></tr>
</table>



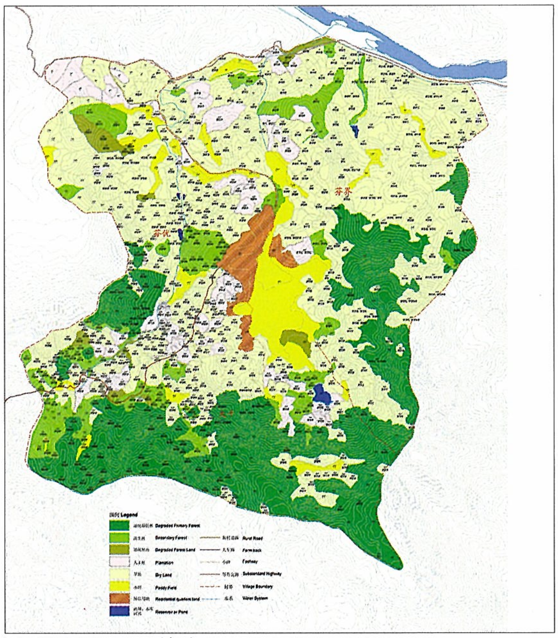
2009 年森林景观镶嵌图　Map of forest landscape mosaic in 2009



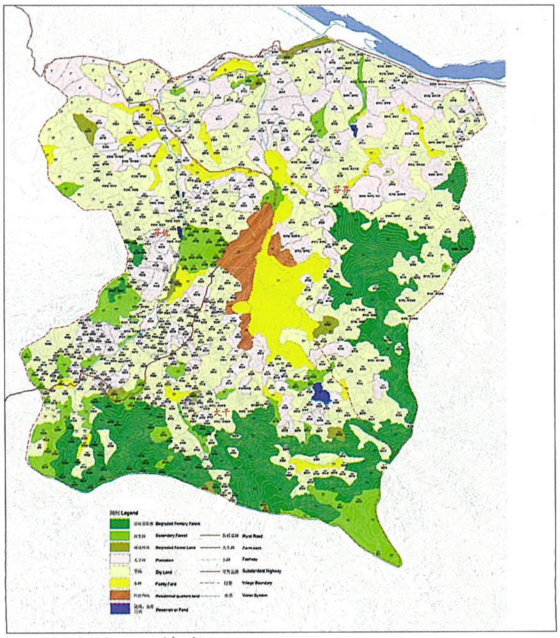
图例　Legend

附录 6　大敢 FLR 示范区不同时期森林景观镶嵌图

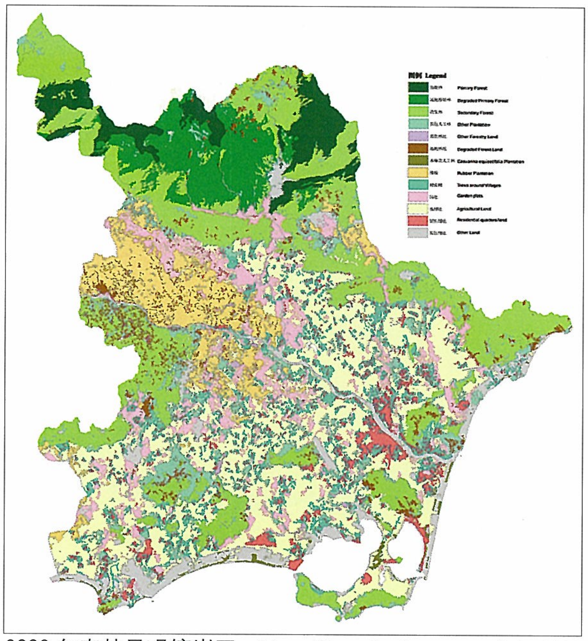
Annex 6　Maps of forest landscape mosaic of Dagan FLR demonstration area in different periods



1990 年森林景观镶嵌图　Map of forest landscape mosaic in 1990



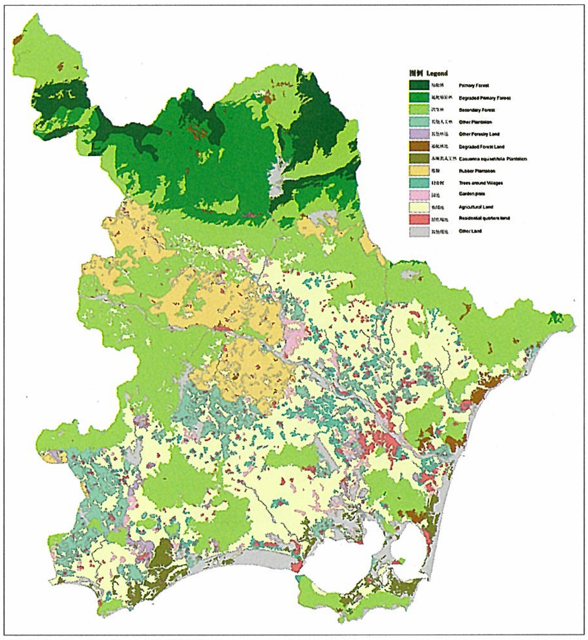
1999 年森林景观镶嵌图　Map of forest landscape mosaic in 1999



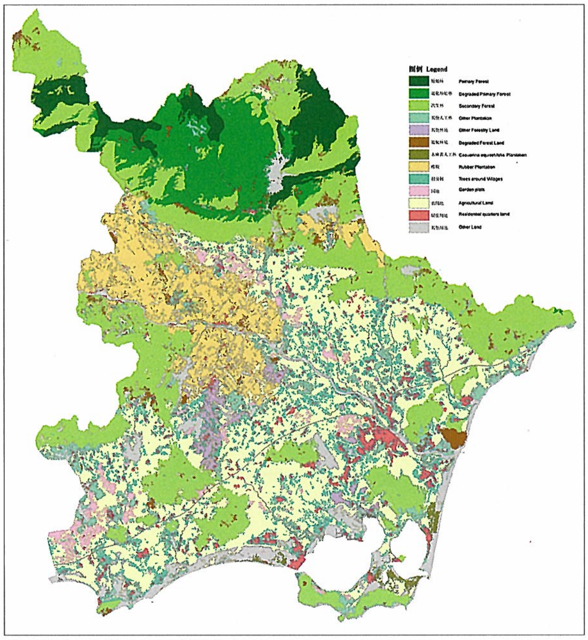
2008 年森林景观镶嵌图 Map of forest landscape mosaic in 2008

图例 Legend

附录 5　陵水黎族自治县不同时期森林景观镶嵌图
Annex 5　Maps of forest landscape mosaic of Lingshui Li Autonomous County in different periods



1991 年森林景观镶嵌图　Map of forest landscape mosaic in 1991



1999 年森林景观镶嵌图　Map of forest landscape mosaic in 1999

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