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ANALYSIS

Accounting for India's forest wealth

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ABSTRACT

In this paper, we account for forest wealth in India. Changes in the timber and carbon wealth embodied in these forests are related to important green national accounting aggregates such as genuine saving and the change in wealth per capita. Important accounting issues include the timing of carbon releases that occur when forests are disturbed, as well as the valuation of these releases. Our empirical findings suggest that while India's forest wealth is substantial, net changes in this wealth are arguably not so large at least in relation to GNP. However, when viewed in the context of the wealth-diluting effects of population growth this implies a far larger *additional* savings effort is required to cover the (net) loss in forest values than otherwise appears to be the case. Finally, we examine ways in which the accounting approach that we adopt can be reconciled with approaches which stress conserving forest wealth.

1. Introduction

Efforts to improve the treatment of forest resources in national accounts offer a number of policy useful benefits. Firstly, an accounting approach provides a consistent and coherent framework for analysing detailed and diverse data describing the net welfare cost of clearing forests. Secondly, given one particular focus of these accounts on the better measurement of income and wealth, they are ideally suited to measuring those losses in wealth that occur when, for example, land-use is switched from forest to other uses. In this way, the depletion of forests in the developing world (and elsewhere) is inextricably linked to current concerns about the measurement of sustainable development. Pezzey (1989) offers a widely cited definition that a development path is sustainable if welfare per capita does not decline along that path. Achieving sustainability, in turn, has been equated with propositions regarding how an economy should manage its wealth over time. For example, key propositions in this respect include that of weak sustainability—which emphasises changes in the real value of wealth in the aggregate and strong sustainability which (typically) also emphasises the conservation of critical natural capital (for which there are essentially no substitutes).

The primary goal of this paper is to extend this empirical discussion of sustainability to the domain of tropical forests and, in particular, to the case of India's forests. Our approach takes into account not only timber values but also carbon that is accumulated in standing forest or, conversely, the carbon

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that is released when forest is cleared or harvested. A large number of empirical studies have focused on accounting for the net accumulation of timber that arises when forest is cleared or harvested (see, for example, Repetto et al., 1989; Van Tongeren et al., 1993; Vincent, 1999a; Seroa da Motta and Ferraz, 2000; Hassan, 2000; Haripriya, 2000a, 2001). A number of other studies have attempted to account for the value of net carbon accumulation or sequestration, with Anielski (1992) for Canada providing one of the first (physical) accounts of this type and Hassan (2000) for South Africa offering a recent example using monetary values. Depending on the shadow price of a unit of carbon used, Nordhaus and Kokkelenberg (1999) speculate that carbon stored in trees has a social value 'comparable' in terms of its empirical importance to commercial values. This is borne out in studies such as Atkinson et al. (2004) which look at the permanent clearance of forestland in Peru.

A number of studies have constructed accounts that encompass a wider notion of land value across a range of developed and developing countries (see, Vincent and Hartwick, 1997, for a review). Thus, forestry accounts exist for non-timber forest products (NTFP) (e.g. Bartelmus et al., 1993; Hultkrantz, 1992), environmental services such as watershed services and soil conservation functions (e.g. Aguirre, 1996; Van Tongeren et al., 1993; Hassan, 2000) and fuelwood (e.g. Peskin, 1989). Fewer studies have estimated the value of biodiversity, although Hultkrantz (1992) proposes an estimate, for Sweden, based on the opportunity costs of conserving land. A particularly novel treatment is Vincent et al. (1993) for Malaysia, which seeks to account for the value of species extinction. More recently, Haripriya (2000a) accounted for the pharmaceutical benefits of forests in India based on an estimate of option value. There have been fewer attempts to comprehensively account for the value of tropical forests, see Torres (2000) and Atkinson et al. (2004). The latter of these studies conclude that, given current knowledge, about local and global willingness to pay for the benefits of standing forest, a comprehensive measure of net accumulation in the forest sector is dominated by changes in net timber and carbon accumulation rather than the (net) loss of other values. This suggests that, from an empirical perspective, there is a stronger rationale for focusing forest accounting efforts on timber and carbon. This is essentially the approach that we take in the current paper.

The contribution of this paper is the following. First, we provide the first application (to our knowledge) of a forest account to India that seeks to provide a comprehensive picture of both timber and carbon wealth. Second, we link this empirical exercise to the on-going discussion of sustainable development and, in particular, current proposals to measure sustainability with reference to savings rules based either on assessing (net) changes in total wealth or changes in per capita wealth. Third, we provide a further discussion than in previous accounting studies of the appropriate shadow value of a unit of carbon and the 'correct' treatment of the transboundary or global nature of climate change damage. Fourth, we account for the carbon embodied in harvested timber that is typically released over time. To the extent that these future additions to the atmosphere carbon stock or liability can be predicted, it makes sense to make an appropriate allowance for these releases in current measures of say net saving. Lastly, given that many would argue that tropical forests are critical resources, we link our accounting efforts to concerns about strong sustainability, which emphasises the conservation of natural wealth.

2. Accounting framework

2.1. Green national accounting: theory

While this paper is concerned with the estimation of an 'adjusted' account for forest wealth, it is important to place this empirical work in the relevant theoretical context. The literature on green national accounts arises from a concern that economic indicators, such as Gross National Product (GNP), do not reflect the depletion and degradation of the environment and so may lead to incorrect development decisions, in much the same way that cost–benefit analyses do not include the values people place on the environment which may yield poor investment decisions. This literature builds on important contributions by Weitzman (1976), Hartwick (1990) and Mäler (1991). The framework in most contributions is "extended Hicksian" as the focus typically is on accounting for the value of changes in total wealth in national income. National income is typically defined along the (optimal) path of a growth model for a simple economy with stocks of goods (including natural assets used in production) and bads (including environmental liabilities that negatively affect utility). A generalised expression for (net) national income aggregate is:

$$\mathrm{NNP} = C + \Sigma p_i \dot{X}_i = C + G \tag{1}$$

where NNP is equivalent to the dollar value of consumption (C) plus the sum of net changes in i assets ($\dot{X}_i$) each valued at its shadow price (p_i). Alternatively, this can be written as consumption plus adjusted net or genuine saving (G). An interpretation of NNP is that it measures extended Hicksian income: that is, the maximum amount of produced output that could be consumed at a point in time while leaving wealth (instantaneously) constant (Pemberton and Ulph, 2001). Given an interpretation of sustainability that the change in the (real) value of total wealth should not be negative in the aggregate, this definition of Hicksian income suggests that our focus should be on genuine saving or G. The reason for this is that G tells us about (net) change in wealth in that it can be shown that (Dasgupta and Mäler, 2000):

$$\dot{W} = 0 \text{ if } G = 0 \tag{2}$$

That is, the change in the present value of utility ($\dot{W}$) or wealth is zero if genuine saving is zero. More specifically, the key finding in this literature is that a point measure of $G_t < 0$ means that a development path is unsustainable (Hamilton and Clemens, 1999).[3] That is, negative genuine saving implies that the level of utility over some interval of time in the future

[3] The finding that negative genuine saving is unsustainable holds for (characterisations of) non-optimal development paths (Dasgupta and Mäler, 2000).

must be less than current utility—development is not sustained, to use Pezzey's (1997) terminology. Moreover, Hamilton and Hartwick (2005) and Hamilton and Withagen (2004) show that positive G results in development being sustained so long as the rate of change in G is no greater than the interest rate: that is, for example, an outcome which can be achieved by a policy rule of constant (positive) net saving.

Pearce and Atkinson (1993) provided one of the earliest suggestions for a practical indicator–which Hamilton (1994) later termed 'genuine' saving–based on this notion that negative net saving should be avoided. Estimated rates of genuine saving for a broad range of countries are now published annually by the World Bank (e.g. World Bank, 2003). These data make it clear that *persistently* negative genuine saving rates characterise a number of countries at various periods over the past three decades.

An important development is offered by Dasgupta (2001) and Hamilton (2003) in response to the question as to how sustainability should be measured when population is growing. That is, G measures only the change in total wealth whereas, in much of the developing world, the reality is that population is growing at relatively rapid rates. This means that total wealth must be shared amongst even more people. In such circumstances, the net change in total wealth per capita is a better measure of sustainability. This can be written as follows (Hamilton, 2003):

$$\frac{d}{dt}\left(\frac{W}{N}\right) = \frac{\dot{W}}{N} - \frac{gW}{N} = \frac{G}{N} - \frac{gW}{N} \quad (3)$$

where W is total wealth, N is total population and g is the population growth rate. Hence, the net change in total wealth per capita, $d/dt(W/N)$, is equal to change in total wealth (i.e. $\dot{W}$ or G) divided by total population (N) minus the product of total wealth per capita (W/N) and the population growth rate (g). Ferreira et al. (2003) refer to this latter component of the (right-hand side of the) above expression as a 'wealth-dilution' term. Put another way, it represents the sharing of total wealth with the extra people implied by a country's growth in population. Clearly, for a population growth rate that is strongly positive then $d/dt(W/N)$ could provide a very different signal to policy-makers about sustainability prospects than the 'traditional' genuine savings rate. Both indicators, therefore, are important and we make use of both in what follows.

Lastly, it is worth noting that a number of contributions such as Ekins et al. (2003) have sought to construct indicators of changes in critical natural capital: that is, where forest services and climate functions are maintained by holding relevant stocks and liabilities at target physical levels. While the approach that we adopt in this paper is primarily concerned with deriving indicators of the monetary value of changes in forest wealth, we discuss further below the important issue of the consistency of this with explicitly strong sustainability approaches.

2.2. *Accounting for forest wealth*

The specific case of forestry, and in particular deforestation, has been explored in models by Hartwick (1992, 1993), Vincent and Hartwick (1997), Vincent (1999b) and Atkinson et al. (2004). Typically, these models result in terms for: (i) the net accumulation of timber lost when forestland is permanently cleared and/or 'plantation' timber is harvested; (ii) the net accumulation of carbon in forests. (Interestingly, however, as we discuss below, theoretical contributions appear to disagree on how to account for carbon damages.); and, (iii) a term reflecting the (net) increase in the land asset value from switching from standing forest to some other use, typically agriculture in many developing countries. For example, Vincent (1999b) and Atkinson et al. (2004) show that this term reflects the difference between the present value of the economic activity that displaces standing forest on a unit of land and the present value of a range of forest services that are lost in perpetuity when forest is permanently cleared. If deforestation was optimal then we would expect these two terms to be equivalent.[4] However, in a world of policy distortions and market imperfections, there are good reasons to argue that deforestation is non-optimal. This could lead to *excess* deforestation where "excess" can be interpreted as deforestation yielding a decline in the *social* value of the land. Put another way, where distortions prevail, the value of the activity on the alternative (non-forest) land-use could well be less than the value of the standing forest it displaces (because of forest-related externalities).

Atkinson et al. (2004) provide the first (full) empirical application of this excess deforestation term by comparing the marginal returns to agricultural land in Peru and a range of factors such as the welfare enjoyed by citizens in Peru and rest of the world from a hectare of land under standing forest. This study concludes that while the size of this excess deforestation term is non-trivial, it is not as significant a determinant of net accumulation in forest resources as that associated with timber and carbon values. While establishing whether or not this finding is generalisable is an important matter for future research, we do not explore this accounting term any further in the current paper.

2.3. *Accounting for transboundary CO_2 damages*

A critical question regarding accounting for net carbon accumulation concerns the 'correct' treatment, in the accounts for a study country, of the transboundary or global nature of the climate change problem. That is, how should our study nation (India) account for the climate change implications of losing its forests? There are two possible responses to this question both of which have been proposed elsewhere in the literature.

On the one hand, it could be argued that as national accounts typically measure the welfare (or, at least, the economic transactions) of citizens within a given country, green national accounts should measure the negative welfare effects of climate change suffered by citizens within the study country only. This suggests that India should account for the adverse consequences for its citizens (in terms of climate change impacts) arising from its own carbon dioxide (CO_2) emissions and those emissions occurring in the rest of the

[4] When land clearance is costly there is some additional term reflecting investment in land-use change that must be taken account of.

world. This is essentially the approach of Vincent and Hartwick (1997) and Vincent (1999a,b). We refer to this as the 'national welfare approach'.

On the other hand, it might be argued that what is of interest is the social cost or damage that is directly identified with the generation of the polluter's income. This implies that India should account for the damage that its own emissions of CO_2 causes anywhere in the world (i.e. whether in India or elsewhere). Adverse impacts in India caused by CO_2 emitted abroad would itself be accounted for elsewhere (i.e. in the accounts for the rest of the world). This is essentially the approach taken, explicitly, by Hamilton and Atkinson (1996) and, implicitly, by Hassan (2000). We refer to this as the 'social cost approach'.

Table 1a summarises the implications of these divergent approaches. This describes shadow prices for carbon, *b*, and carbon emissions, *e*, from India and the rest of the world (RoW). For example, $(b_{\text{India,RoW}})\times e_{\text{India}}$ describes the damage that India's carbon emissions cause in the rest of the world. Thus, for the case of India, the national welfare approach (e.g. Vincent and Hartwick, 1997) suggests deducting the India *column sum* from that country's NNP. The social cost approach (e.g. Hamilton and Atkinson, 1996) suggests deducting the India *row sum* from that country's NNP.

What are the practical implications of choosing between these two different approaches? Clearly, global NNP is the same whichever method is adopted. However, for our study country, it is likely that the two approaches will give different answers to the question of what is 'true' income in the presence of climate change damages; that is, it is clear that from Table 1a that each is measuring different things. Of course, exactly how different is an empirical matter and from Table 1, this amounts to a comparison of $(b_{\text{RoW,India}})\times e_{\text{RoW}}$ and $(b_{\text{India,RoW}})\times e_{\text{India}}$. In other words, is damage in India caused by emissions in the rest of the world greater or less than damage caused in the rest of the world by emissions in India? In the present context, our reference point is the impact of net carbon released by disturbed forests in India and so the relevant question is whether the social value of this net carbon embodies (net) costs imposed only on residents of India or those living anywhere in the world.

Interestingly, it is not possible to actually make straightforward comparisons between these approaches using published data from say Integrated Assessment Models (IAM) which represent the main source of information on climate change damages in the literature. As a proximate illustration, Table 1b offers an empirical example. Data on (industrial) carbon emissions are taken from World Bank (2003) and a value of *b* equal to \$20/tC is assumed. A key issue is how much of this total is attributable to damage that occurs in India (and, by inference, the rest of the world). We assume that $b_{\text{i,India}}$ = \$1/tC and $b_{\text{i,RoW}}$ = \$19/tC: that is, when a tonne of carbon (tC) is emitted it causes \$20 of damage, \$1 of which can be accounted for by adverse impacts in India and the remaining \$19 of which is due to (net) damage in the rest of the world. While this is a working assumption, inferences from the climate change damage literature indicate that it is broadly defensible.[5] A number of points, arising from Table 1b, are worth noting. First, the amounts to be deducted from NNP and *G* are respectively the column sum for India for the national welfare approach and the corresponding row sum for the social cost approach. Interestingly, these values are little different from each other, i.e. \$6157 million and \$5889 million, respectively. Hence, in this example, there is little difference in the magnitude of the climate change debit to NNP or *G*–about 1.4% of India's GNP in 1999–whichever approach is taken (although the rationale for either deduction is very different).[6] Second, there is significant difference as regards to how India should account for its *own* emissions and sequestrations of carbon. In the case of national welfare approach, only damages which fall on the population of India would be debited. From Table 2, this amounts to \$294 million or about 0.1% of GNP in 1999. By contrast, under the social cost approach, an amount equal to \$5889 million or about 1.4% of

Table 1

Damages	Emissions		
	India	RoW	Row sum
(a) Accounting for carbon damage: two approaches			
India	$(b_{\text{India,India}})\times e_{\text{India}}$	$(b_{\text{India,RoW}})\times e_{\text{India}}$	Total damage caused by India's emissions of CO_2
RoW	$(b_{\text{RoW,India}})\times e_{\text{RoW}}$	$(b_{\text{RoW,RoW}})\times e_{\text{RoW}}$	Total damage caused by Rest of world's emissions of CO_2
Column sum	Damage suffered in India as result of total emissions of CO_2	Damage suffered in Rest of world as result of total emissions of CO_2	Global damage caused by global emissions of CO_2
(b) Accounting for carbon damage: \$million (m) 1999			
India	\$294 m	\$5,595 m	\$5,889 m
RoW	\$5,863 m	\$111,388 m	\$117,251 m
Column sum	\$6,157 m	\$116,983 m	\$123,140 m

Emissions data are carbon from industrial sources (World Bank, 2003). Data for calculation are: e_{India} = 294 mtC; e_{RoW} = 6136 mtC; $b_{\text{i,India}}$ = \$1/tC; $b_{\text{i,RoW}}$ = \$19/tC.

[5] For example, Nordhaus and Boyer (2000) estimate for a 2.5 °C rise in mean global temperature damages arising in India might range from 2.7% to 4.6% of its Gross Domestic Product (depending on whether the possibility of catastrophic impacts is included). Comparing, in dollar terms, the value of damage in India to the value of (net) global damages indicates that the former make up roughly 5–7% of the latter. While there are numerous caveats, this indicates that for a social cost of carbon of \$20/t C then–very approximately–the amount of this value arising because of (unit) damage occurring in India is \$0.9–1.4.

[6] It should be noted that this finding is explained by the approximately equal ratios of e_{India}: e_{RoW} and $b_{\text{i,India}}$: $b_{\text{i,RoW}}$. (see notes to Table 2). For $b_{\text{i,India}}$ well below \$1 (or well above \$1), then other things being equal, the national welfare approach will generate values more substantially in excess of (or below than) the social cost approach.

Table 2 – Estimates of marginal damage of carbon emissions in $/tC (1995 prices)

	Carbon damage ($/tC)	
	Low ($)	High ($)
Base-case	5	10
Equity weighting	5	25
Base with time-varying discounting	7	18
Equity weighting with time-varying discounting	7	45

Source: Pearce (2003).

GNP would be debited. Clearly, from the perspective of accounting for the carbon value of India's forests, these divergent approaches will give very different signals regarding the social value of this component of India's forest wealth.

While both calculations outlined above provide interesting (but potentially different) information, which is the 'correct' accounting approach? This is an important question as it entails asking how much a country should save in order to cover this (net) accumulation of a climate change liability. However, it is arguably not a question that can be easily answered using formal approaches to green national accounting. Rather it must be judged on the basis of additional economic reasoning and, indeed, is not dissimilar to discussions in cost–benefit analysis about 'who has standing'. In this respect, we offer the following comments in the context of savings rules.

The national welfare approach provides an apt description of actual future prospects under the assumption of no international action to tackle carbon emissions. Put another way, the 'downwind' (or victim) country has no property right to climate 'stability'. This results in an accounting rule that reflects this "victim-pays" thinking. As such, under this approach, if India wishes to stay on a sustainable path then it must, other things being equal, save enough to cover the value of (future) climate change damages that occur within its national boundaries *regardless* of the geographical origin of the (current) emission source that gives rise to these damages.

The social cost approach, in contrast, proposes a basic extension of the *polluter pays principle* to the domain of national accounting (Hamilton and Atkinson, 1996). In other words, (climate change) damage caused anywhere in the world by emissions from India should appear as a deduction from the income of that country. In terms of measuring (weak) sustainable development, the foregoing requires that some portion of India's total savings should, at least notionally, be set aside in order to compensate the recipients of the damage arising from e.g. CO_2 emitted and transferred across international boundaries. Other things being equal, a polluting country is 'less sustainable' because of the liability it is accumulating in the form of the climate change damage it causes in other countries (as well as itself).

The choice between these two approaches essentially boils down to a judgement or prediction as to the nature of international climate change negotiations in determining how property rights are allocated across countries. That is, the national welfare approach in effect assumes a world where there is no prospect for a meaningful and sustained climate change treaty to exist. The social cost approach in effect assumes that such a treaty either exists or is a realistic prospect. Clearly, neither assumption is a wholly satisfactory description of the real world where the current prospect for international agreement is characterised by uncertainty or where a study country faces under obligations to reduce its emissions of greenhouse gases under current arrangements. However, the existence of an international climate change regime at least gives some support for the view that (net) carbon emissions are at least a notional liability in the green national accounts of the country where the carbon release takes place. Hence, we use the social cost approach in the remainder of this paper, although we comment on the sensitivity of our findings to far lower assumed values of carbon.

2.3.1. *Shadow price of carbon*

Net carbon accumulation is valued using an estimate of the shadow price of carbon drawn from the climate change damage literature. This price conveys information about the present value of (future) damages caused by a tonne of carbon (equivalent) emissions and is usually calculated using IAMs (Mendelson, 2003).[7] A widely cited early value –currently used by World Bank (2003) in estimating genuine saving–is Fankhauser (1994). That study estimated that the dollar (present) value of the damage caused by a tonne of carbon emitted in the mid-1990s is $20 (in the range of $6–45). However, a well-known finding in this literature is the large variation in estimates of the marginal damage arising from greenhouse gas emissions (see, for a review of past studies, Tol et al., 2001). Nevertheless, Tol (2004) argues persuasively that this variation should not be taken to mean that any value can be justified (or rejected) and the relative merit of existing studies can be assessed with reference to clear and broadly agreed criteria. Such an assessment does not, unsurprisingly, result in one 'consensus' value for the social cost of a tonne of carbon. Rather it narrows down the range within which this value might (in all likelihood) plausibly fall.

A large-scale meta-analysis of past climate change damage studies by Tol (2004) concludes that social costs might fall in the range of $10/tC to $20/tC. Recent reviews by Tol et al. (2001), Pearce (2003) and Tol (2004) have also sought to take stock of the available evidence about the 'most likely' (best guess) values of climate change damage. These reviews typically make a distinction between those estimates based on "first-generation" models of climate change damage (e.g. Fankhauser, 1994) and estimates based on, more recent, "second generation" models. The conclusions of the review by Pearce (2003) are summarised in Table 2. The base-case is that the best guess is in the range of $5/tC to $10/tC (in 1993–1994 prices). This range is lower than indicated by first

[7] An alternative way of evaluating the shadow price of a tonne of CO_2 is with reference to the likely price at which carbon might trade at if say there was a (global) trading system to allow countries to achieve Kyoto targets. Nevertheless, OXERA (2002) shows that predictions regarding this price indicate a large variation between studies in the range of $14/t C to $85/t C. Indeed, evidence from actual carbon trades to date indicates a similarly large range of 2/t C to $43/t C (Natsource, 2001).

generation estimates: a finding which is attributable to more sophisticated treatments of adaptation (particularly in the agricultural sector) in more recent estimates. However, other notable developments in the literature have served to boost estimates of the social costs of carbon. Two of these developments in particular are worth considering in more detail.

First, beginning with Fankhauser et al. (1997), the incorporation of explicit judgements about equity has been a distinguishing feature of recent efforts to value climate change. This has entailed giving greater weight (than in earlier studies) to those damages that fall on countries where citizens have relatively low per capita incomes. From Table 2, it can be seen that this widens the likely range of estimates of the social cost of a tonne of carbon to $5/tC to $25/tC. Not surprisingly there is controversy regarding the precise weight to assign to damages suffered by citizens of low-income countries. For example, in parallel to criticisms of distributional cost–benefit appraisals, Mendelson (2003) argues that climate change policy is not the appropriate instrument with which to address concerns about (global) income distribution. Others such as Pearce (2003) appear to broadly support the equity weighting approach but counsel against using unjustifiably high estimates of inequality aversion, i.e. values which appear to have no basis in actual decision-making (as revealed say in aid distribution to the world's poor).

Second, it is well known that the magnitude of the (social) discount rate will have a significant bearing on estimates of the social cost of carbon. For example, Tol (1999) finds damages of $73/tC, $23/tC or $9/tC depending on whether the discount rate takes a (constant) value of 0%, 1% or 3%, respectively. More recently still, a number of studies have explored the implications for valuing climate change damage of non-constant (i.e. time-varying) social discounting (see, for a recent review, Groom et al., 2003). In terms of the social costs of carbon, time-declining discount rates–by slowing the rate of decline in discount factors–give greater weight to climate change impacts that occur in the far-off future. Pearce (2003) argues that this has had the effect of roughly doubling estimates of the social cost of carbon (relative to the base-case) and extends the range of values from $7/tC to $19/C (Table 2, row 3).

Combining these two recent analytical concerns gives rise to damage estimates in the range of $7/tC to $44/tC (Table 2, final row). Thus the range indicated in Table 2 accords with recent contributions by Tol et al. (2001) and Tol (2004) where it is argued that damage values in excess of $50/tC are not justified in that these typically assume impacts which are extremely unlikely or take overly strong ethical positions (e.g. positions not easily reconciled with revealed social behaviour).

Of course, some uncertainty surrounds the likely influence on estimates of risks of catastrophic climate-related outcomes, which are lacking in almost all studies to date. It is reasonably asserted that incorporating extreme impacts into IAM studies would lead to substantial upward revisions of estimates of the social costs of carbon. However, Link and Tol (2004) find that this conclusion is not necessarily straightforward to confirm. The authors examine the shutdown in thermohaline circulation in the Atlantic Ocean in IAM estimates. Interestingly, their calculations indicate that marginal damages with and without the catastrophic outcome arising are little different, largely due to the fact that relative to the 'business-as-usual' case one likely consequence is that this particular impact slows-down warming (amongst other effects).

While the above discussion narrows the range of possible estimates, selecting likely ranges suggested by this literature is clearly not straightforward. In what follows we adopt a value of $20/tC as our central estimate of the social cost of carbon; that is, at the upper end of the range of meta-estimates of Tol (2004) and solidly in the middle of the range suggested by Pearce (2003). In addition, we comment on the implications of assuming significantly lower and higher estimates of $5/tC and $40/tC (at the bottom end and towards the upper end of the range indicated in Table 2, respectively).

3. Case study of India's forest wealth

3.1. Data

3.1.1. *Opening stocks*

The opening stocks represent the stock of forest resources (area under forests or the volume of growing stock) present at the beginning of the accounting period. The opening stocks are taken as the total growing stock present at the end of the 1991–1993 assessment made by the FSI.[8] The total opening volume is 4,740,858,000 cubic metres (cum) and the forest area present at the beginning of the period 1993–1994 is 639,600 km^2 (1 km^2 = 100 ha). To convert this estimate into units of carbon, we need the estimates of biomass. In India, as estimates of biomass using direct measurement (destructive sampling) are not available for all forest types in the country, a study by Haripriya (2000b, 2002a) used the volume inventory data to estimate the carbon content of the biomass. According to the study, the biomass density/ha in Indian forests is around 92 t/ha (Haripriya, 2002a). The biomass data are converted to carbon values by assigning a carbon content of 0.5 Mg C per Mg oven dry biomass. Using this estimate the opening stock of carbon in Indian forests is 2933.8 million tonnes. We have included only the aggregate carbon content of forest biomass and did not include the stock of carbon in soils. The rationale for including this only is that we are interested in the change in carbon as a result of "disturbance" on forested land in the current accounting period.

3.1.2. *Changes due to economic activity*

Changes due to economic activity refer to the human production activities such as logging/harvest, logging damage,

[8] FSI assesses the comparative situation of forest cover in the country once every 2 years and published in the FSI (1995a). The latest estimates of growing stock were done for the period 1991–1993 and published in FSI (1995b). As no other estimates of growing stock were available for the country at the time of carrying out the study, the study period is chosen as 1991–1993. The study uses the closing stocks of 1991–1993 as the opening stock for the year 1993–1994.

illegal logging and afforestation that affect (decrease/increase) the stock of forests. To compute the changes in carbon stock due to economic activity, information on the total volume of timber harvested, area subject to logging, illegal logging and area afforested is required. The volume of timber harvested/logged is derived from the production statistics of timber and fuelwood for the year 1993–1994. The area subjected to logging is derived from the volume accounts by dividing the total volume harvested by the growing stock per square kilometer.[9] As logging involves logging damage, the study considers logging damage as well (we assumed that 10–15% of the total volume harvested either remains on the stump or is damaged). However the volume of timber harvested for timber and fuelwood is highly debated as the estimated consumption exceeds the recorded production. The study considers the amount of logging done illegally in Indian forests also (see Haripriya, 2000a, 2001, 2002b).

While computing the total volume of carbon "lost" (or harvested) one should include (a) carbon transferred to forest products (in the form of biomass), (b) releases of carbon from forest biomass into the atmosphere while clear cutting or partial cutting, and (c) releases to the soil pool, etc. (see Appendix to this paper for details of these calculations). As the timber can be logged either by clear felling or partial cutting, one has to consider the respective carbon balances by different methods (see Haripriya, 2003). The study by Haripriya (2003) has assumed that when the logging is done by clear-cutting only 80% of the stem biomass is transferred to the wood products, whereas 2% remains on the stem, 8% is transferred to soils and 11% is released to the atmosphere. When the forest is subject to partial cutting 85% of the stem biomass is transferred to wood products, 10% remains on the stump and 5% is transferred to the soils. The amount of carbon remaining on the stem or transferred to soils gives the amount of logging damage. Another point to be noted here is that from the standpoint of national accounting, we have defined the change in carbon as the present value (future) carbon released arising from disturbances (e.g. logging) on forested land in the current accounting period. In other words, it does not matter that the carbon in forest products is not released in 1993–1994. The key thing is that the logging activity occurred in this period and these future releases can be predicted (a point we return to in Section 3.2 below). Based on this the total carbon leaving the biomass is estimated at 83.38 MtC. This includes the transfer of carbon to the atmosphere as well as to the soil.

The area afforested in India is 6796 km^2 during 1993–1994 (information provided in ICFRE, 1995).[10] However, it is not clear if the total area afforested also includes the area under compensatory afforestation. The study assumes that the recorded figure includes compensatory afforestation carried out in different states. Further, the statistics reported at the national level do not indicate various species planted, the survival rate of these plantations, how much area actually ends up forested and the growing stock per ha in these afforested areas. The volume additions due to afforestation are derived by multiplying the area afforested with the mean annual increment per square kilometer of different strata.[11] Based on this the mean annual additions to timber is 0.85 million cum. The amount of carbon sequestered is 0.48 million tonnes.

3.1.3. *Other accumulations*

Other accumulations consist of the accumulation of timber due to natural growth (mean annual increment), natural regeneration, and the transfer of forestland for non-forest uses (for example, for agriculture, residential or industrial purposes). The mean annual increment of different species is taken from the statistics published by the FSI (1995b). The total annual increment in India according to 1993 assessment is 87,622,000 cum. This volume estimate is converted to units of carbon using the same method as discussed before. Based on this the mean annual accumulation of carbon in biomass is 49.34 million tonnes of carbon.

In addition there is also some amount of regeneration in forests. Only the information on area regenerated in various states is available and the volume added due to regeneration is computed by multiplying the area regenerated with the mean annual increment per ha of different species.[12] The carbon increases due to natural regeneration is assumed to be offset by loss in carbon due to surface fires and grazing. Some of the forest area is transferred for non-forest purposes. The total area transferred in India was 64,600 ha during the year 1993–1994. The volume reduction due to transfer of land for nonforest purposes is derived by multiplying the area transferred with the growing stock per ha. Around 3.4 million tonnes of timber is lost due to this transfer of forestland. The timber available from this land is included in the logging statistics and hence not considered here again.

3.1.4. *Other volume changes*

Other volume changes comprise reductions (due to stand mortality, insect infestation, forest fires and natural calamities) and transfer of land from economic use to forests. Fires can be of two types: surface fires (non-stand replacing) and crown fires (stand replacing). As the surface-fires are non-stand replacing fires they are not considered under other volume changes and only the stand replacing fires are considered. Based on the data for 1985–1988 compiled by the Ministry of Environment and Forests (MOEF), FSI (1988) estimated that the stand replacing fires affect about 10,000 km^2 annually. The same percentage area has been taken as annual area affected by stand replacing fires for the reference year 1993.

[9] Due to the ban on clear felling in some states in India, the statistics on area logged are not available. However, the volume of timber logged is available. In the absence of data on area logged, the volume of timber logged is used to obtain the information on the area logged.

[10] A 3-year average from 1991 to 1994 is used so as to avoid any lags in data reporting.

[11] The assumption was made as the information on volume of stock growing in afforested area is not available.

[12] As a result of frequent fires and heavy grazing only 18.3% of the total forest area has regeneration potential of important species (FSI, 1995a). However, statistics on stratum wise regeneration is not available hence are derived by multiplying the area regenerated with the corresponding weights of the forest strata. The percentage of area under different strata is used as weights.

The volume of forest stock affected by forest fire is derived by multiplying the naturally regenerated volume and the afforested volume with the percentage area affected by the forest fire.[13] Haripriya (2003) estimated that when the forest is affected by fires, only 20% of the stem biomass remains, 50% is burnt and the carbon is transferred to the soils (immediate and releases that eventually occur in future as a result of fires today) and 30% is released into the atmosphere. The total amount of carbon lost (or released to the atmosphere) is estimated at 24.34 million tonnes of carbon. Here the change in carbon is defined as the present value of (future) carbon released arising from disturbance on forested land in the current accounting period).

As the forests are infected by pests, only insect infestations resulting in loss of biomass are explicitly considered in the study. Recent insect induced mortality data are not available in India and the latest statistics available at the time of this analysis are the estimates of loss in timber volume due to insects, pests and diseases from Indian Forest Statistics (various years between 1947 and 1972) for various states. This study also assumes the same proportion of insect related volume loss for 1993. The area disturbed due to mortality of trees is derived from the volume accounts by dividing the volume lost due to mortality of trees with the growing stock per hectare. The volume estimates are converted to carbon estimates as discussed before. The total carbon released out of the woody biomass is around 0.46 million tonnes of carbon.

The area subject to grazing is taken from FSI (1995a) and the volume lost due to grazing is derived by multiplying naturally regenerated volume and the afforested volume with the percentage of area subject to heavy grazing.[14] However, no carbon loss is assumed from grazing because the carbon increases due to natural regeneration is assumed to be offset by loss in carbon due to surface fires and grazing.

There are varying estimates on actual area subject to shifting cultivation in different states. The net area subject to shifting cultivation (after excluding the regenerated areas) is around 951 km^2 (Haripriya, 2001). The volume lost due to shifting cultivation is obtained by multiplying the area subject to shifting cultivation with the growing stock per ha, which is 7.04 million cum. The total carbon released as a result of shifting cultivation includes (a) releases for forest biomass into the atmosphere and transfer to the soils, which account to 0.39 million tonnes of carbon. Here we have assumed that 80% of the carbon is transferred to the wood products and only the rest is released. Again the change in carbon is defined as the present value of (future) carbon released arising from disturbance on forested land in the current accounting period.

3.1.5. *Closing stocks*

The closing stocks are computed as opening stocks less reductions plus additions. The closing stock of timber is 4704 million cum while that of carbon is 2865 million tonnes.

3.1.6. *Valuing net timber accumulation*

Value accounts for timber have been derived using the net price method. Various volume entries in the physical accounts are multiplied with the net price of (timber and fuelwood) to obtain the value accounts. The net price method assumes that the value of resource at the beginning of period t (R_t) is the volume of the opening stock multiplied with the difference (N_t) between average market value per unit of the resource (P_t) and the per unit marginal cost of harvest, development and exploration (C_t) and is given by $V_t = (P_t - C_t)R_t = N_t R_t$. In this paper, instead of marginal costs we used average costs. Once the value of the opening stocks and closing stocks are determined by net price method, net accumulation can be calculated by subtracting the value of the opening stock from the value of closing stock. Though several studies have supported the use of net price method, Vincent (1999a) mentions that the net price method is typically only an approximation of the true change in the asset value of timber, and could more probably over or under-state the correct magnitude of (net) timber accumulation. One reason for this is due to the divergence between the marginal and average costs. Most of the studies using net price method use average costs instead of the marginal costs (including the present paper). The net price method, thus, over estimates depreciation since it also accounts for differential/Ricardian rent or quasi-rents and not only scarcity rent as theoretically indicated.[15] Hence, some studies have advocated the user cost approach for computing the net accumulation of natural resource stock. However, user cost approach requires information on the optimal rotation age and the age structure of different stands, which we do not have. Hence, we retain the net price method in what follows and as mentioned in some earlier studies, the estimates may be viewed as an upper bound on the likely value of depletion of timber resources.

In the case of carbon we used an estimate of $20/tC for valuing carbon releases. Some of the carbon estimates needed discounting in order to estimate the present value of future releases of carbon which are attributable to disturbances to standing forest in the study period. For this we used a discount rate of 5.9%. (This is based on an estimate of a social discount rate for India based on an estimate of the social rate of time preference.) Lastly, we assume that the shadow price of carbon grows at a rate of 1% per annum reflecting the findings of Fankhauser (1994).

3.2. *Results*

Table 3 summarises our basic findings, for 1993–1994, in terms of: land under standing forest; the physical volume of timber and carbon; and, the monetary value (i.e. billions of Rupees) of timber and carbon where the latter is valued at $20/tC (or about 630 Rupees). In terms of a land area account (Table 3,

[13] Only the forest area that is prone to frequent fires is considered as affected by fire annually in this study. Further, only regenerated volume and afforested volume is considered affected by forest fire, as it is only the young saplings, which are generally affected by fire.

[14] In the construction of physical resource accounts only the forest area subjected to heavy grazing is considered as it leads to the destruction of stumpage trees. It is assumed that moderate and light grazing does not cause much damage to the forests.

[15] We would like to thank the reviewer for raising this point.

Table 3 – India's forest wealth: summary physical and value account

	Volume account				Value account		
	Land [a] (mil. ha)	Timber [a] (mil. cum)	Carbon (mil. tonnes)	Timber [a] (bil. Rupees)	Carbon (bil. Rupees)	Timber (% of GDP)	Carbon (% of GDP)
Opening Stocks	63.96	4740.86	2933.77 [b]	9519.87	1841.35	101.71	19.67
Changes due to econ. activity							
Logging	−1.85	−122.83	−83.38 [b]	−234.27	−49.84	−2.50	−0.53
Logging damage [c]	−0.19	−12.28	−8.34	−23.43	−4.98	−0.25	−0.05
Afforestation	0.68	0.85	0.48 [d]	1.63	0.30	0.02	0.00
Other volume changes							
Forest fires	−6.50	−3.61	−26.41 [b,e]	−7.38	−11.33	−0.08	−0.12
Stand mortality	0.00	−0.50	−0.46 [b]	−0.97	−0.13	−0.01	0.00
Grazing	−11.71	−5.51	−3.10 [d]	−10.62	−1.95	−0.11	−0.02
Shifting cultivation	−0.10	−7.04	−4.58 [b]	−12.75	−2.34	−0.14	−0.02
Other accum							
Net growth	–	87.62	49.34 [b]	169.06	30.97	1.81	0.33
Regeneration	0.07	29.93	16.85 [d]	58.60	10.58	0.63	0.11
Transfer of land	−0.07	−3.40	−1.91 [d]	−5.47	−1.20	−0.06	−0.01
Closing stocks	–	4704.08	2872.26	9454.30	1811.43	101.01	19.35
Changes in stocks	–	−36.78	−61.51	−65.57	−29.92	−0.70	−0.31

a Timber volume and value data from Haripriya (2001).
b Carbon volume data from Haripriya (2003).
c Logging damage is assumed to take a value of 10% of the logging harvest.
d Carbon volume per unit of timber biomass assumed to be same as for natural growth and valued at $20/tC.
e In case of forest fires, the carbon lost is higher than timber lost because carbon is mostly released from ground biomass and from trees with diameter less than 10 cm which is not included in the timber accounts.

column 2) it can be seen that though forests are disturbed due to animal grazing, forest fires and logging, the loss in timber and carbon values as a result of grazing is not much. However forest fires do have a large impact on release of carbon to the atmosphere. The annual losses due to release of carbon due to forest fires and loss in timber is 0.04% and 0.08% of GNP in India. Though the area subject to logging is less it translates into higher timber and carbon values. The contribution of forests due to harvesting timber contributes to 2.5% of GNP. However, the corresponding carbon loss due to usage of forests for timber and fuel wood is 0.53% of GNP.

In terms of the volume accounts, Table 3 (column 3) shows that opening stocks of timber are 4741 million cum. The largest single category of decreases in the physical stock of available timber over the period is that of logging (123 million cum) (an activity which itself leads to damage to surrounding trees of an assumed 10% of the harvest). Other negative volume changes such as fires and stand mortality (arising from infestations) account for a far lower (combined) total loss of timber. Timber stocks are increased most notably by natural growth (88 million cum) followed by regeneration of land (30 million cum). The closing stock of timber taking account of these losses and gains in volume is 4704 million cum: i.e. an overall decrease of some 37 million cum. In money terms (column 5), the value of the total stock of timber was about 66 billion Rupees lower at the end of the accounting period than at the beginning of the period (i.e. 9520 billion Rupees minus 9454 billion Rupees).

The physical volume of carbon released (now and in the future) as a result of these activities is illustrated in column 4. This refers to carbon embodied in tree biomass: e.g. stem, foliage and root biomass, etc. Opening stocks of carbon are 2934 million tC while closing stocks are 2872 million tC. That is, there is a net loss of carbon in timber biomass of roughly 62 million tC. It should be recalled, however, that not all of this carbon is released into the atmosphere in the current period: column 4 describes all (undiscounted future) gains or losses in carbon arising from disturbance in the current accounting period. For example, in the case of carbon released as a result of logging, the total volume of carbon 'lost' includes (a) biomass transferred to (forest) products; (b) releases to fast/medium soil pools, etc.; and (c) current releases of carbon from forest biomass into the atmosphere. In essence, it is only the latter that contributes for climate change now. That is, this carbon is instead transferred to forest products or soils respectively and released in future periods.

From the standpoint of valuing carbon released a result of logging activity, the treatment of (c) is relatively straightforward: i.e. current releases multiplied by the shadow price of carbon. For (a) and (b) the appropriate accounting procedure is less straightforward. Two alternative approaches are worth considering. On the one hand, if carbon transferred to say soils is subsequently released into the atmosphere sequentially over a number of years then it could be argued that the value of the damage caused should appear as a debit in the accounts in the year of release.[16] On the other hand, it seems reasonable to suggest what we should account for all future effects of disturbing forestland in the current accounting period. The value of the change in carbon could then be defined as the present value of (present and future) carbon released as a result of disturbances (e.g. logging) on forested land in the current accounting period. (See Appendix to this paper for

[16] Cairns and Lasserre (in press) set out a conceptual framework which accords with this approach.

details of these calculations.) Thus, it does not matter that the carbon in e.g. forest products is not released in 1993–1994. The key thing is that the logging activity occurred in this period. Put another way, to the extent that future releases of carbon owing to forest disturbances 'today' can be predicted and measured, it is prudent to make allowance for the value of these releases–suitably discounted–when producing greener estimates of income, net saving and wealth.

Within Table 3, the timing of these (net) carbon releases is reflected in the valuation of carbon (column 6). For example, in the case of logging, a substantial proportion of this carbon is released immediately–i.e. in the current period–because the transfer of biomass to timber products such as fuelwood which are used to fulfil, for example, current household energy needs. A smaller proportion of timber biomass is used to create more durable products such as furniture. In such cases, the carbon embodied in these products is released at a time beyond the current accounting period. Table 3 (columns 5 and 6) indicates that, in all cases, the value of timber stocks lost exceeds the value of carbon damage for an assumed shadow price of carbon of $20/tC.

The magnitude of these changes in relation to GNP is illustrated in columns 7 and 8. For net timber accumulation, depletion arising from logging is equivalent to −2.5% of GNP. This is offset to a large extent by the timber value of natural growth (1.8% of GNP) and regeneration of previously cleared land (0.6% of GNP). However, other losses of timber (due to forest fires and so on) mean that net accumulation of timber is −0.7% of GNP. Net accumulation of (forest) carbon is equivalent to −0.3% of GNP where its largest negative and positive components being logging (−0.5%) and natural growth (0.3%), respectively. On balance, net timber and carbon accumulation in India's forests is about −1% of GNP. This magnitude gives an indication of the additional savings effort required in order to avoid negative genuine savings as a result of activities in the forestry sector.

One final point worth making about Table 3 is that arguably the value of timber and carbon stocks cannot simply be added. The asset value depends on the use to which it is ultimately put to, i.e., while standing forest provides timber and carbon as joint products the full value of each cannot be enjoyed simultaneously. For example, if a unit of forestland is valued as a store of timber then at some point when trees are harvested, carbon will be released (or as we described it in this paper, events are set in motion that leads to current as well as eventual releases of this carbon). The point is that the value of this forest stock consists of its timber value *plus* its carbon value where the latter corresponds to the value of the (estimated) postponed carbon release. Hence, if the forest were to be clear-cut in five years and used to make non-durable wood products then the stock value of the carbon now would be the value of the postponement of the climate change contribution for that time. As we do not have specific information on specific use of forests, we have kept these two values separately.

Table 4 illustrates findings for the carbon value of changes in forest wealth (as a percentage of GNP) under alternative assumptions about the social cost of a tonne of carbon. First, column 2 in the table, evaluates the change in carbon value for $5/tC. This is reflected in the net change in carbon value

Table 4 – Valuing carbon in the forest accounts: alternative assumptions

	Damage as a percentage of GNP under different assumptions about the social cost of tonne of carbon (*b*)		
	b = $5	*b* = $20	*b* = $40
Opening Stocks	4.92	19.67	39.35
Changes due to econ. activity			
Logging	−0.13	−0.53	−1.06
Logging damage	−0.01	−0.05	−0.10
Afforestation	0.00	0.00	0.01
Other volume changes			
Forest fires	−0.03	−0.12	−0.24
Stand mortality	−0.00	−0.00	−0.00
Grazing	−0.01	−0.02	−0.04
Shifting cultivation	−0.01	−0.02	−0.04
Other accum			
Net growth	0.08	0.33	0.66
Regeneration	0.03	0.11	0.22
Transfer of land	−0.00	−0.01	−0.02
Closing stocks	4.84	19.36	38.72
Changes in stocks	−0.08	−0.31	−0.62

See notes for Table 3.

arising from forest activities in India which is less than −0.1% of GNP. Second, column 4 in the table, evaluates the change in carbon value for $40/tC. In this case the net change in carbon value is about −0.6% of GNP, with logging and logging damage equivalent to −1.2% and the carbon value of natural growth adding 0.7%. At a superficial level, these results do not add much to our discussion: that is, if the social cost of carbon is say doubled then the effect of this on aggregate calculations are obvious. Nevertheless, these 'sensitivities' are important given they reflect different assumptions about the significance of climate change as a (global or national) policy problem. On the one hand, a higher (than $20) estimate of carbon's social cost gives a better indication of (global) carbon value of India's forests when climate change is reckoned to be far more serious in aggregate terms perhaps because of stronger ethical preferences than is typically assumed. On the other hand, a lower estimate of carbon's social cost gives an indication of the carbon value of India's forests on the basis that climate change is far less more serious a problem than often thought or, recalling our earlier discussion (Section 2.3.1), may be more indicative of the carbon value of India's forests if policy-makers in India are only concerned with the damage that climate change causes for the Indian population now and in the future.

How do these values compare with other relevant green national accounting terms in India? One way of assessing this would be to examine the genuine savings rate for India in 1993–1994. Table 5 combines our summary data for forestry with data from World Bank (2003). Genuine savings is equal to gross savings plus education expenditures (as a proxy for the accumulation of human capital) minus depreciation of produced capital, depletion of energy and mineral resources, damage caused by industrial CO_2 emissions and changes in forest wealth (as previously defined). The table shows that

Table 5 – Genuine saving in India: 1993/4

	Genuine saving as percentage of GNP
Gross savings	20.4%
−Depreciation	9.8%
−Energy depletion	2.6%
−Mineral depletion	0.5%
−Industrial CO_2 emissions	1.5%
+Education expenditures	3.6%
−Net forest depletion	1.0%
Of which:	
Timber depletion	0.7%
Net carbon accumulation	0.2%
=Genuine saving	8.6%

Source: Net forest depletion—authors' own estimates; all other data—World Bank (2003).

genuine saving was 8.5% of GNP with the last term decreasing its value by 1.1% of GNP.

In terms of its relation to GNP, our findings with regards to the net change in forest wealth in India indicate that this magnitude is significant but possibly no greater than 1%. However, this measure of total asset change does not tell the whole story. Population growth in India was about 1.8% over the period 1993–1994. Following Hamilton (2003), this gives rise to a "wealth dilution" effect. Positive growth rates of population imply that an additional savings effort is required in order to keep the real value of per capita (net) wealth constant. Expression (3) above described this indicator of the change in *total* wealth per capita. The analogous expression for forest wealth (W_F) is: $d/dt(W_F/N)=(\dot{W}_F/N)-g(\dot{W}_F/N)$ where W_F, in principle, is made up of the timber and carbon value of forests. For illustrative purposes, in the light of the preceding discussion about summing these (possibly competing) values, we use only our data on timber wealth. Table 3 (column 5) indicates that the closing stock of W_F was equal to 9454 billion Rupees. For a population level of 908 million, W_F/N is about 12,420 Rupees. This means that the 'wealth dilution' effect in the case of forest wealth is equal to 187 Rupees or 1.8% of GNP per capita. Given that $(\dot{W}_F/N)=-72$ Rupees, the *total* change in forest wealth per capita is equivalent to be *at least* 2.5% of GNP per capita. This is an empirically more significant magnitude than is the case when the wealth diluting effects of population growth are ignored. Put another way, an additional savings effort of some 2.5% of per capita income is needed to sustain forest wealth in per capita terms. Given that India's gross saving rate per capita during this period was 20.4% of per capita GNP or 2080 Rupees, this magnitude is equivalent to more than 12% of these savings.

Performing this analysis in per capita terms requires that we have an estimate of total wealth. World Bank (1997) presented cross-country measures of total wealth and its components. These data relate to the year 1994 but give a proximate guide to the level of wealth in India in our study period. Hence, we combine data on non-forest commercial wealth in India (specifically relating to: produced assets, sub-soil assets, and agricultural land) with the data presented earlier in e.g. Table 3 on forest wealth (timber only in this example). Table 6 (final row) shows that the change in total wealth per capita was negative (i.e. −1647 Rupees). That is, the superficially robust positive rate of genuine savings is not enough to sustain development when the savings analysis is conducted in per capita terms. Table 6 also indicates the components of this wealth dilution term. It can be seen that the (timber) value of forests accounts for just below 10% of this term (which is otherwise mostly determined by the value of agricultural land and produced assets).

3.2.1. *Strong sustainability*

For many, accounting for India's forest wealth within the typical terms of reference of green national accounting falls foul of the imperative to view forests as an explicitly strong sustainability problem. That is, in the context of forests, a guiding principle should be the protection of absolute levels of ecological goods that are provided by standing forest. The rationale for this management rule is that the diminished capacity of these complex systems to provide (irreplaceable) environmental functions is likely to be place highly undesirable burdens on human well-being or even survivability (see, for example, Norton and Toman, 1997; Ekins et al., 2003). Clearly, it is important to consider this perspective and its implications for the accounting approach that has, thus far, been adopted in this paper.

On the one hand, it is overly simplistic to claim that so-called 'weaker' approaches to accounting mean that forest wealth can be liquidated almost with impunity. Studies such as, for example, Torres (2000) demonstrate that incorporating available estimates of the market and non-market value of forests can provide a powerful rationale for a significant increase in forest conservation. More ambitious studies such as Costanza et al. (1997) have similarly sought to demonstrate the value of conservation more generally. With regard to the case of forestry, given that a substantial proportion of deforestation occurs because of what can be broadly termed 'policy failures' then correcting these failures is a recommendation regardless of whether proponents are of a weak or a strong (sustainability) persuasion.

On the other hand, while a variety of forest-related ecological phenomena (such as natural growth) underpin our summary account in Table 3, it remains true that these data do not capture the idea of critical thresholds or, more specifically,

Table 6 – Change in wealth per capita in India: 1993–1994

	Changes in total wealth (Rupees per capita)
Genuine saving per capita (G/N)	796.7
Wealth dilution (gW/N)	−2444.1
Of which:	
Produced assets	747.6
Sub-soil assets	81.9
Agricultural land	1425.9
Forest assets: timber	188.7
Change in wealth per capita	−1647.4

Source: Forest depletion—authors' own estimates (Table 5; World Bank, 1997).

to what extent thresholds are being reached or perhaps even breached. If, however, India's forest wealth is a natural asset characterised by important limits on exploitation, then a genuine concern is that if exceeded this might lead to large-scale and irreversible ecological losses with possibly dramatic implications for negative impacts on human well-being. In such a case, it would be a misguidedly 'daring', and not to say foolhardy, decision to exploit a critical asset such that its stock is driven below its threshold or critical level. Assuming that policy-makers wish to avoid such recklessness, the key issues then are the identification of critical assets, their threshold levels and indications regarding how serious for human well-being a breach of a relevant threshold is likely to be. Just as pertinent is sensible guidance regarding decision-making when there is uncertainty about any (or all) of these parameters.

Even accepting the view that forests are critical natural capital, this leaves open the question of how this insight is interpreted either as a condition for sustainable development or, by implication, its inference for constructing indicators of forest wealth. A simple rule of thumb would be to say that India's forests should be left intact at the current level, in which case a casual glance at Table 3 might indicate that this condition is plainly not being met (at least at the aggregate level). Of course, in reality, even an apparently simplistic approach can quickly descend into relatively complicated discussion about whether this constraint to preserve the current stock refers to say the global (i.e. India's tropical forests as one component of global forests), national (i.e. India) or regional (i.e. India's individual states or some other geographical emphasis).

Numerous candidate indicators of strong sustainability exist which might be relevant for the problem of accounting for forest wealth. For example, Chambers et al. (2000) estimate ecological footprints which compare required forested area implied by a country's economic activity and actual forestland available to that country. Another notion is that of a critical or minimum area of forest that must be preserved intact. For example, Kramer and Mercer (1997) cite an 'expert consensus' that maintaining the integrity of the global rain forest ecosystem would require protection of, at least, a given proportion of remaining forest. However, in assessing the quantity of land either to be protected or the area actually protected, matters are complicated in that there are a range of sustainable forestry options between the extremes of 'fence-and-forget' conservation and liquidating the forest asset. Indeed, many of these options balance–in varying combinations–market (tangible) and non-market (intangible) values. As an example, agroforestry–i.e. mixing trees with farming–offers one means of achieving a greater balance between commercial production with carbon storage and biodiversity protection relative than 'fence and forget' or (certain) modern agricultural practices. Indeed, it has been argued by a number of forestry experts that agroforestry not only itself provides ecological benefits but also protects such functions supplied by nearby protected forest areas and, moreover, allows farmers to capture at least some of the benefits of forest conservation thus helping to ensure that these benefits will be sustained (Schroth et al., 2004; Pearce et al., 2002). In practice, therefore, sustainability indicators should also be linked to this wider set of policy options.

Can the notion of strong sustainability be reconciled with the accounting approach that we have drawn upon in this paper? There are two positive responses to this question, although–at present–it is only the second of these that constitutes a workable approach.

One way of capturing the strong sustainability notion of a critical amount of a resource or natural asset is by assuming that: $p_i \to \infty$ as $X_i \to \bar{X}_i^{+}$, where $\bar{X}_i^{+}$ is the critical amount of the ith natural asset (and which might correspond to land area in the case of forest) (Atkinson et al., 2004). That is, as the resource declines to the critical amount, arbitrarily large losses in welfare are associated with depletion of a marginal unit. In principle, the resulting adjustment to NNP and G would show up as a correspondingly large loss in value of the critical natural asset (i.e. as its stock level reaches the critical amount). If preferences for critical resources are taken into account, then the most socially desirable policy is to be strongly sustainable (i.e. set limits on resource depletion so as to avoid the prospect of rapidly increasing losses in welfare). In practice, however, this approach runs into questions about the sufficiency of available scientific and economic information for preferences to be relied upon to reflect the appropriate trade-offs that would underpin this willingness to pay estimate.

Another related approach would be focus on the essential idea that a given physical amount of the forest resource must be preserved intact does not mean that the standard green national accounting approach can be altogether discarded. To see this, an analogy can be drawn with the implications of the concept of a safe minimum standard (SMS) in such terms whereby policy-makers follow standard cost–benefit rules unless there is a compelling reason not to, e.g. to conserve a critical natural asset (Farmer and Randall, 1998).[17] In terms of indicators of sustainable development, Pearce et al. (1996) provide an illustration of how this two-tier approach might operate in the case of a given area of forest. In this example, preserving some quantity of the forest is considered to be critical for the long-term well being of humanity and that rapid deterioration in forest quality occurs once a critical threshold has been breached. The effect of this preservation is to reduce the amount of forest that can be considered to be an economic resource (i.e. it reduces the quantity of harvest that can be carried out from the non-conserved stock). The key indicators for a forested country operating under this regime are twofold: are stocks of this critical natural asset declining; and are genuine savings rates (i.e. savings net or the change in the non-conserved resource stock), or change in per capita wealth, negative? A positive answer to either of these questions would be an indication of unsustainability. This illustrates that, in general, it is not credible to think that either a single indicator that can describe all relevant aspects of the development path. A better picture of whether countries are developing sustainably will ultimately require a judicious mix of distinct but complementary indicators.

[17] However, this conservation rule can itself be overridden if its costs are "intolerable".

4. Conclusions

Accounting for forest wealth has a number of policy useful benefits including the provision of a framework for analysing detailed and diverse data. The wealth account that we have presented for India's forests has described forestry-related stocks and flows in terms of land area (under forest), physical volume (of timber and carbon) and, finally, monetary values. All of these accounts are useful extensions of standard approaches. However, it is the final 'type' of account and its concern for the better measurement of forest income and wealth–and, in turn, its link to the measurement of sustainable development–that has been the primary focus of this paper.

This focus has given rise to a number of issues. For example, if such accounts are to extend beyond timber values, there are important issues that need to be confronted as regards the shadow price of carbon. Not only does this entail choosing between (a range of) estimates of the social cost of carbon–and the uncertainties that accompany these estimates–but also, according to some, judging whether social cost (in the sense of *all* global damage arising from a study country's carbon dioxide emissions) is the 'correct' emphasis for *national* accounting, green or otherwise. In reviewing these issues, we have argued that, even for a study country such as India, accounting for the social cost of carbon releases is a useful exercise. Interestingly, although not a reason in itself for preferring one approach over another, the alternative perspective–that only the cost to India's citizens of own emissions should be accounted for–implies values which are not empirically significant.

Another issue is that disturbances to forestland over the accounting period cause a stream of impacts now and into the future. For example, in the case of carbon values, when forests are disturbed because of say timber harvest then carbon is transferred to soils and timber products. Only over time is this transferred carbon is released into the atmosphere. The (net) change in forest wealth is, therefore, the present value of all of these future impacts caused when forests are disturbed in a given accounting year. Hence, our estimates have taken into account the *timing* of carbon releases attributable to events in our period of study. This results in rather different implications for the significance of notably carbon values than would prevail for the simple assumption that when forests are disturbed, 'lost' carbon is immediately released. In other words, climate change impacts are postponed because of the delayed release of transferred carbon and our accounting framework takes explicit note of this.

Our empirical findings suggest that while India's forest wealth is substantial, net changes in this wealth are arguably not so large at least in relation to GNP. However, neither is the overall size of these flows trivial and when viewed in the context of the wealth-diluting effects of population growth in India implies a far larger *additional* savings effort is required to cover the (net) loss in forest values than otherwise appears to be the case. Important issues remain, most notably how to combine the accounting approach that we adopt in this paper with the insights of those who advocate strong sustainability with its distinctive emphasis on conserving say forest wealth in some way. Both approaches are valuable and useful but arguably neither is wholly satisfactory on their own. Reconciling these approaches, in practical ways, is an important matter for future research.

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Appendix A. Estimating changes in carbon asset values

Appendix A.1. Depreciation of disturbed biomass

The volume of disturbed biomass in period 0 (our study year) can be converted to its mass in terms of tonnes of carbon as follows: $\alpha T(0) = C(0)$, where: T is cubic metres of disturbed biomass; α is tonnes of carbon per one cubic metre of disturbed biomass; and C is carbon transferred from disturbed biomass.

This carbon is transferred from standing forest to the atmosphere (e.g. in the case of slash-and-burn), wood products (in the case of partial clearance from harvest) and the forest floor: $C(0) = C_A(0) + C_R(0) + C_S(0)$, where: C_A is carbon directly transferred to atmosphere; C_R is carbon transferred to wood products; C_S is carbon transferred to soil.

Appendix A.1.1. Atmosphere

Carbon transferred into the atmosphere represents releases or emissions of carbon in period 0. The value of these releases is simply the product of the shadow price of carbon and emissions:

$$b(0)C_A(0)$$

where b is the shadow price of carbon.

Appendix A.1.2. Timber

Carbon transferred to wood products can be embodied in non-durable products or durable products: $C_R(0) = C_R^N(0) + C_R^D(0)$; where C_R^N is carbon in non-durable wood products, C_R^D is carbon in durable wood products.

Carbon embodied in non-durable wood products is released in period 0. However, carbon embodied in durable wood products transferred is gradually released in subsequent periods when these wood products reach the end of their economic life and are disposed of. In each period, therefore, some proportion of this carbon is released: so that the amount of carbon released in year t is e.g. $d_R(t)C_R^D(t)$; where d_R is the rate of depreciation or release of carbon from durable wood products and $C_R^D(t)$ is the remaining amount of carbon left in these products at the start of period t.

The present value of gradual releases of carbon transferred to wood products in period 0 is:

$$b(0)C_R^N(0) + \sum_{t=1}^{n} d_R(t)C_R^D(t)b(0)\frac{(1+g_b)^t}{(1+r)^t}$$

where r is the discount rate; n is the number of years over which depreciation takes place (assumed to be 200); and g_b is the growth rate of the shadow price of carbon.

Appendix A.1.3. Soil

Releases resulting from carbon transferred to the soil pool present similar calculation issues to that of durable wood products. The complication is that there are m different pools of this transferred carbon: fine materials (relatively rapid carbon release), coarse (relatively moderate carbon release) materials and soil (relatively slow carbon release) (Haripriya, 2003). Moreover, fine and coarse materials either result in releases of carbon to the atmosphere either directly from that pool or via a further transfer to soil. Abstracting from this final detail, what this means is that carbon transferred to each pool i is associated with its own depreciation rate (d_S).

The present value of gradual releases of carbon transferred to these different pools in period 0 is:

$$\sum_{i=0}^{m}\sum_{t=0}^{n} d_{S_i}(t)C_{S_i}(t)b(0)\frac{(1+g_b)^t}{(1+r)^t}$$

Appendix A.2. Natural growth

Biomass before disturbance ($\bar{T}$) is subject to a rate of natural growth ($g_{\bar{T}}$). This natural growth is valued as follows: $\alpha g_{\bar{T}}\bar{T}(0)b(0)$. That is, the quantity of carbon in this growth of the opening stock of biomass in period 0 is valued by the (undiscounted) shadow price of carbon.

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