Developed-developing world partnerships for sustainable development (2): an illustrative case for a payments for ecosystem services (PES) approach

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Abstract

The Converging World (TCW) developed-developing world partnership model represents a transparent approach to addressing carbon emission management in a mutually beneficial way, with a substantial 'multiplier effect' achieved though reinvestment of operating surpluses from energy generation into tropical dry evergreen forest (TDEF) restoration. Carbon dioxide is averted/sequestered at a theoretical cost of £0.0058 £ per tCO_2e (≈ $US0.01 per tCO_2e). For the City and County of Bristol, England, cumulative century-long CO_2e emissions of 256,550,000 tCO_2e could be matched by one-off investment of £3:56 for each of Bristol City's 442,500 population in commissioning a 2.1MW wind turbine in Tamil Nadu under the TCW model. Similar considerations apply at institutional level; indicative contributory investment in turbine installation is calculated for a case study institution. Calculated investments relate to the 'anchor service' of climate regulation, though the TCW model also generates multiple co-beneficial ecosystem services serving local people and addressing UN Sustainable Development Goals. Restoration of other bioregional habitats could yield additional socio-ecological benefits. TCW's aspirational investment model positions social return on investment (SROI) as primary 'interest', rather than maximisation of financial returns to investors. We test the case for founding developing world investment on the basis for 'payments for ecosystem services' (PES).

Keywords

Renewable energy, climate change, restoration, economics, sequestration, resilience

Research highlights

- A developed-developing world partnership offers mutual carbon management benefits

- Reinvesting profits from renewable energy sales in forest restoration amplifies carbon abated

- Investment by developed world partners in linked generation-restoration is cost-effective

- Multiple service co-benefits from habitat restoration are significant, but require valuation

- Sustainability is advanced by framing socio-ecological gains as 'interest', not private profit

1. Introduction

Sustainability challenges have increasingly to be tackled on a collaborative international basis. This is due to the transboundary and global nature of many common ecosystems, their associated problems and necessary management responses as for example climate stability, air pollution, fishery and other oceanic and large catchment systems. Ethical factors also demand international responses, particularly redressing the asymmetric distribution of benefits and threats resulting from historic, geographically skewed resource exploitation and development. There is a strong economic case for international responses in an increasingly globalised economy, as threats arising in one region can ripple through global markets in the forms of resource access and limitation, political turbulence, investor and customer confidence and a range of other market-influencing factors.

At an intergovernmental level, a range of these issues are subsumed into the 17 UN Sustainable Development Goals (United Nations, 2015). Many SDGs reflect the duty of already-developed states to assist developing nations with poverty alleviation and related development targets, although all relate to the goal of achieving 'The Future We Want' in developed and developing countries alike. These international commitments build upon, and are supported by, a range of developed world aid programmes and redistributive funding arrangements within major trading blocs. However, other international initiatives have a basis in market transactions between developed and developing countries. Examples include Reducing Emissions from Deforestation and Forest Degradation (REDD+), under which developing nations are incentivised to retain carbon stored in forests through conservation and sustainable management (UN REDD, 2014). The Clean Development Mechanism (CDM) is another financially based example, allowing nations with emission-reduction or emission-limitation commitments to implement emission-reduction projects in developing countries thereby earning saleable certified emission reduction (CER) credits as a contribution to meeting Kyoto Protocol targets (UNFCCC, undated). The World Bank was also established on a market basis to reduce poverty by promotion of foreign investment into and international trade with developing countries in support of capital programs (World Bank, undated). An increasing number of international

'payment for ecosystem services' (PES) schemes are also being established, under the terms of which developed world interests pay into developing world schemes targeting ecosystem service enhancements. These international PES schemes can address multiple services including carbon storage (REDD+ is an example), water resources, and livelihood and biodiversity security (OECD, 2010; UNEP and IUCN, undated).

Everard *et al*. (submitted) advances a set of expanded PES-related principles as a test for the robustness and transparency of market-based developed-developing world partnerships for sustainable progress. These principles are summarised in Box 1 with detailed descriptions in Everard *et al*. (submitted), but building upon foundational principles established by Wunder (2005), augmented by Smith *et al*. (2013) and integrating the 'systemic solutions' approach (Everard and McInnes, 2013). Ideally, decisions and management actions should account for the spectrum of ecosystem services and their beneficiaries. However, in practice, one or a few ecosystem service outcomes generally form the principal driving forces in scheme instigation. Historic practice generally prioritises maximisation of production of a focal service fitting a commercial, regulatory, or other desired end-point. This may be, for example, food or water production often for private profit, whilst overlooking potential externalities for other services and their (often public and/or non-marketed) beneficiaries. Everard (2014) describes how these driving forces for service enhancement can instead constitute an 'anchor service' around which solutions are sought, ideally in collaboration with other stakeholders in resource management and its outcomes, to optimise the co-delivery of inevitably interconnected services thereby seeking to optimise net societal benefit, cross-stakeholder equity and the resilience of the productive ecosystem.

Box 1: Expanded PES-related principles (from Everard *et al*., submitted)

Established foundational PES principles (Wunder, 2005) identify that transactions should be:

- **Voluntary**;
- Relate to a **well-defined ecosystem service**;
- 'Bought' by one of more **ecosystem service buyers**;
- 'Sold' by one or more **ecosystem service providers**; and
- **Conditional** on securing ecosystem service provision or executing measures agreed as likely to secure service supply or enhancement.

Additional principles identified by Smith *et al*. (2013) include:

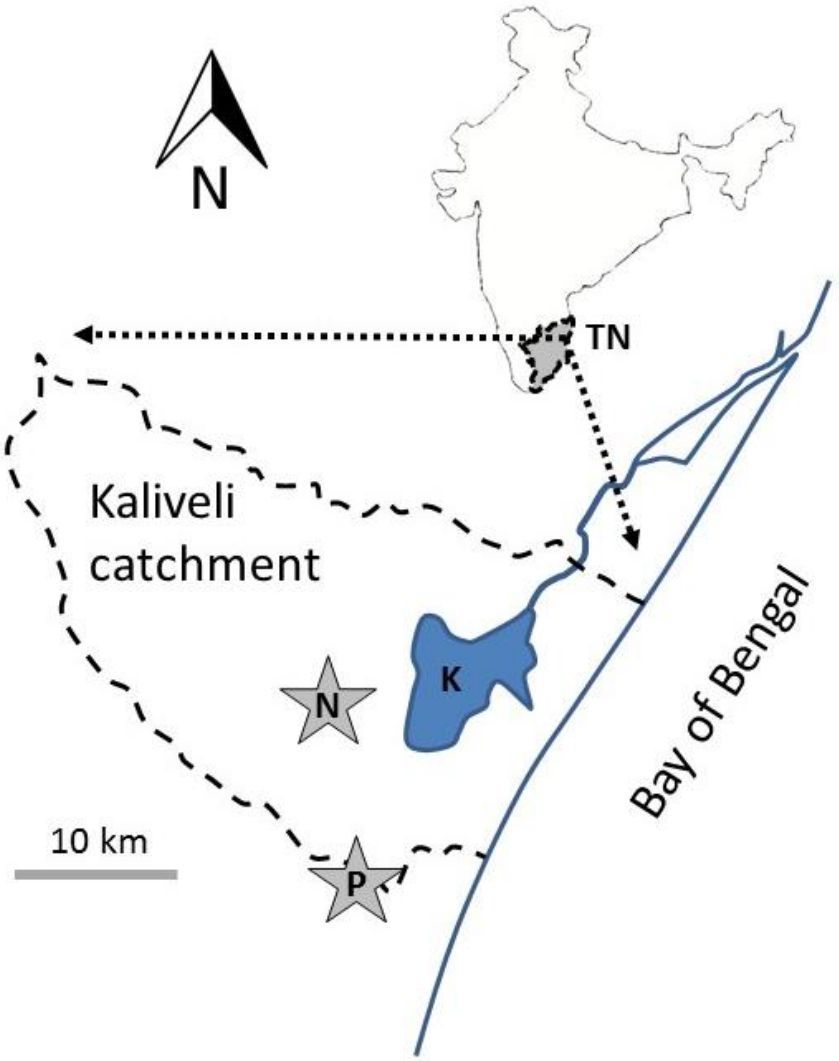
- Obeying the **Beneficiary pays principle**, a pricing approach under which consumers of the service contribute to the costs its production
- **Direct payment** made to ecosystem service providers (often via intermediaries);
- **Additional** to actions resource managers would be expected to undertake;
- **Ensuring permanence**, such that management interventions are not readily reversible; and
- **Avoiding leakage**, meaning that benefits achieved in one location are no achieved by transferring damaging practice elsewhere.

Additional principles based on the 'systemic solutions' approach (Everard and McInnes, 2013) are that:

- Benefit realisation should be based on assessment across the **full range of ecosystem service outcomes**;
- Taking account of the **rights of all beneficiaries** of ecosystem services; and
- Ensuring **net societal value is optimised** rather than skewing benefits to favoured service/beneficiaries whilst overlooking non-focal service outcomes.

Everard *et al*. (submitted) explore the case study of The Converging World (TCW) programme of low-carbon energy development in an established developed-developing partnership between south-west England and Tamil Nadu state, India (The Converging World, 2016). The TCW programme conceptually links these developed and developing world regions as a notional single country. This international conjoined regional approach to promote optimal, lowest cost progress towards an overall lower carbon trajectory is justifiable as climate change impacts are geographically independent of where carbon is emitted, captured or stored. Towards this goal, the TCW Group (operating as a network of non-profit and commercial companies including branches in India) has, at the time of writing, already installed 12.9MW of wind turbine capacity in Tamil Nadu to promote low-carbon development supported by funding from the donor region (south-west England). Benefits accrue from low-carbon energy inputs to the Indian grid, averting emissions from the conventional Indian energy mix. However, the TCW model is based on reinvestment of a significant proportion of operating surpluses from renewable energy sales into eco-restoration of tropical dry evergreen forest (TDEF). TDEF is a regionally representative habitat type, best described as a biome with a number of indicative species and tree types rather than a distinctive species assemblage (Gadgil and Meher-Homji, 1986), that has been severely depleted in the coastal regional of Tamil Nadu over recent decades (Pitchandikulam Forest and Bio-Resource Centre, undated). At the time of writing, a little over 30 acres (just over 12 hectares) of TDEF reforestation has taken place at Nadukuppam in the Kaliveli catchment of Tamil Nadu, with more land available to buy and put into trust as the scheme progresses (Figure 1).

Figure 1: The Kaliveli catchment in Tamil Nadu (TN) state, India, showing Kaliveli Lake (K) and the approximate locations of Pitchandikulam Forest (P) and the Naddakuppam restoration area (N)



Everard *et al*. (submitted) and Everard (2015a) analyse the likely global climate change regulation service outcome (the 'anchor service' in the initial phase of the TCW programme) of this linked renewable energy/eco-restoration programme. Box 2 summarises key input data and assumptions, methods and conclusions from Everard *et al*. (submitted) and Everard (2015a), from which a TDEF sequestration rate of 21,994.28 tCO_2 ha^{-1} $year^{-1}$ is calculated for restored TDEF over a 100-year succession to climax community. (Note that Meher-Homji, 1974, to whom the definitive definition of TDEF is often attributed, characterised TDEF as deriving from dry deciduous forest through disappearance of many typical deciduous species and invasion of some endemic species of the drier eastern half of south India substantially mediated by cultural activity; technically' climax' may not therefore be an entirely accurate way to describe a fully developed TDEF canopy though is used as a shorthand for expressing mature forest.)

Box 2: key input data and assumptions, methods and conclusions from Everard *et al*. (submitted) and Everard (2015a)

Net annual CO_2e emissions averted per 2.1MW turbine relative to India's conventional energy mix were calculated at a highly conservative 4,000 tCO_2e $year^{-1}$ over the turbine's 20-year planned operational life.

Based on sparse published data on soil and biomass carbon storage in both mature and degraded forest of an equivalent type in the local bioregion of Tamil Nadu (therefore leading to significant uncertainties in calculated values), there is an annual CO_2 sequestration rate of 21,995.75 tCO_2e ha^{-1} $year^{-1}$ in restored TDEF. This includes a number of conservative assumptions including:

- A 100-year succession to TDEF climax community is assumed (although evidence from the regenerated Pitchandikulam forest on the adjacent Auroville Plateau suggests that climax TDEF may been achieved in a shorter timeframe of approximately 50 years); and

- Restoration of the Naddakuppum forest is occurring on a baseline of highly eroded farmland rather than degraded forest, though baseline carbon storage for 'degraded forest' is used in these calculations.

The TCW programme has provision for reinvestment of surpluses from renewable energy sales from wind turbines supporting eco-restoration of 6.15 hectares of TDEF annually, cumulatively creating 123 hectares of regenerated TDEF over the 20-year operating life of a 2.1MW wind turbine. Combined CO_2e averted by generation from one 2.1MW wind turbine over 20 years (≈80,000 tCO_2e) added to cumulative CO_2 sequestration by successive blocks within the overall 123 ha of restored TDEF over 100 years assumed to climax community (270,547,756.16 tCO_2) represents a lifetime CO_2e sequestered/averted of 270,627,756 tCO_2e. Overall CO_2 sequestration by TDEF restoration therefore dwarfs the direct CO_2e averted by the 2.1MW wind turbine (which accounts for just 0.03% of the combined total). Year-on-year reinvestment in TDEF therefore represents a powerful 'multiplier effect' on the ecosystem service of global climate regulation. In addition to these 'anchor service' benefits, Everard *et al*. (submitted) and Everard (2015a) also identify a diversity of additional ecosystem services – spread across direct benefits in the form of provisioning, regulatory and cultural services and including indirect benefits stemming from ecosystem functions formerly referred to as supporting services – arising from measures in the TCW programme, particularly those stemming from habitat restoration, which makes significant potential contributions to addressing the UN Sustainable Development Goals.

Testing of the TCW partnership programme with the expanded PES-related principles (Box 1) has found it to represent a valuable contribution, promoting mutually beneficial sustainable development in both the donor (developed) and recipient (developing) regions (Everard *et al*., submitted). The principal purpose of this paper is to make an illustrative economic assessment of the 'anchor service' of global climate regulation. This is acknowledged as tentative, as the data upon which forest carbon sequestration rates is founded are sparse. Nevertheless, the study establishes a preliminary business case for a range of potential regional, institutional and individual donors in the developed world partner region. This study further assesses how valuation of the wider ecosystem service co-benefits and contributions

to resilience by consideration of protection or enhancement of supporting functions might, if quantified, create potential new PES markets. They also constitute a wider range of connected beneficial outcomes contributing to overall social return on investment (SROI), bolstering the case for support by developed world investors.

2. Methods

Installation and operational costs for wind turbines in Tamil Nadu under the TCW programme and their anticipated revenues and surpluses from renewable energy sales to the grid were obtained directly from TCW accounts in December 2015. The extent of planned reinvestment of income from energy sales into TDEF eco-restoration were also obtained from TCW in December 2015. Calculations of potential annual area of TDEF restored on the basis of this annual investment and of the associated CO_2e averted/sequestered were derived from the partner paper (Everard *et al*., submitted).

Calculated financial values relating to the 'anchor service' of global climate regulation were then considered in terms of implications for potential investors and other beneficiaries respectively in the developed world partner (at city, regional, national, institutional and individual scales) as well as to diverse communities in Tamil Nadu.

Implications for valuation of the wider linked ecosystem service co-benefits were then considered, albeit that it was not possible to quantify or monetise these other ecosystem services within the current study.

3. Results

The up-front cost of installation of a typical 2.1 MW wind turbine in Tami Nadu is £1,575,000, based on rounded up-front costs for turbine installation/commissioning (land acquisition, capital, planning, installation, connection, etc.) of approximately £750k per MW (Pers. Comm. Wendy Stephenson, TCW). Over a planned operational life of 20 years, the 2.1 MW wind turbine therefore has an annual linear depreciation of £78,750 $year^{-1}$. Net annual income from each 2.1 MW wind turbine throughout its 20-year operational life equals a conservatively calculated £187,500, assuming annual generation of 3,750,000 units of electricity and a (conservative) sales price of £0.05 per unit (assumptions and calculation in Everard et al., submitted). Overhead costs (insurance, maintenance, etc.) of electricity sales are 20-30%, so applying a (conservative) 30% allowance for overhead yields a net annual operating surplus of over £130,000.

Everard (2015a) calculates a Sterling value of £16,255 per hectare for TDEF restoration, based on conversion of estimates of IN₹ costs per tree (including supply of seedlings, manure, pit digging, transport, planting, mulching, bunding, personnel entailed in maintenance, institutional overheads and contingencies) at a specified density (Pers. Comm. Joss Brooks, Pitchandikulam Bio Resource Centre) in addition to the purchase price of land for TDEF conversion @ £5,000 per acre (Pers. Com. John Pontin, TCW). TCW plans include reinvestment of £100,000 per year of operating surplus into TDEF eco-restoration. This is sufficient to restore 6.15

hectares of TDEF per annum throughout the 20-year operational life of the turbine, yielding a total area of 123 hectares of restored TDEF (with annual blocks maturing in a phased pattern over a century).

Dividing the up-front cost of a 2.1 MW wind turbine (£1,575,000 ≈ $US2,253,850) by total lifetime CO_2 averted/sequestered through the 'multiplier effect' of wind turbine operation and reinvestment in TDEF eco-restoration (270,627,756 tCO_2e) yields a cost per unit tCO_2e sequestered/averted of £0.0058 £ per tCO_2e, or 0.58p per tCO_2e (≈ $US0.01 per tCO_2e, or ¢US1 per tCO_2e). The overwhelming contribution of TDEF restoration to the above value concurs with the findings of the 'Stern Review' (Stern, 2006) that reforestation is one of the most economically efficient means to tackle climate change. The cost-effective figures above compare with a direct return through renewable energy sales of £26.25 per tCO_2e averted over the 20-year depreciation life of the wind turbine alone, emphasising the substantial value added by the 'multiplier effect' of reinvestment in habitat restoration rather than returns of private profit to investors.

The benefits of carbon dioxide savings in Tamil Nadu and south-west England

Although values of CO_2e averted/sequestered have to be treated as preliminary given the sparse data upon which they are based, and associated economic values have therefore be treated as largely illustrative, they are at least indicative of the scale of benefits from the 'anchor service' of global climate regulation. Relating these tentative figures to carbon management aspirations in both Tamil Nadu and south-west England is nevertheless informative about the scale of benefits, opportunities and potential business case for investment in the TCW developed-developing world partnership programme. As the baseline carbon dioxide and economic values are tentative, implications for affected people are based on approximate terms only for the people of Bristol City, south west England, the UK as a whole, and Tamil Nadu.

Implications of climate regulation benefits driven by the TCW partnership programme for Bristol City are significant. The statutory unitary authority area of Bristol City and County of Bristol encompasses the largest city in south-west England and a human population of 442,500 with mean per capita carbon dioxide emissions of 5.8 tCO_2e $year^{-1}$ (Bristol City Council, 2016a), implying annual city-wide carbon dioxide emissions of 2,566,500 tCO_2e $year^{-1}$. Setting aside likely population growth and anticipated reductions in per capita carbon intensity, illustrative cumulative city-wide carbon dioxide emissions would therefore total 256,550,000 tCO_2e over a century. In simplistic terms, this approximates to the 270,627,756 tCO_2e lifetime averted/sequestered CO_2 achieved from the sum of renewable electricity generated and annual reinvestment in TDEF eco-restoration from a 2.1MW wind turbine in Tamil Nadu. Theoretically, an up-front capital fund of £1,575,000 invested by Bristol City for installation of a 2.1 MW wind turbine in Tamil Nadu under the TCW Group model would therefore approximately account for total city-wide emissions over a century. This investment represents one-off investment in an initial year of £3:56 for each of Bristol City's 442,500 population. This may be achieved by any of a variety of means, including for example a direct levy (voluntary or compulsory) or a one-off £7:12 supplementary charge on domestic rates on properties for rate-payers

assumed to comprise 50% of total authority area population. Investment in offsetting future emissions is consistent with commitments made by Bristol City to cut carbon dioxide emissions by 60% by 2050 (Bristol City Council, 2016b).

Extending these same broad approximations to the 5 million people of south-west England, assuming the same mean per capita carbon dioxide emissions of 5.8 $tCO_2e\ year^{-1}$, suggests annual south west England carbon dioxide emissions of 29 million $tCO_2e\ year^{-1}$. Cumulative south west England carbon dioxide emissions over a century would therefore be in the order of 2.9 billion tCO_2e, again overlooking population and per capita emissions fluctuations. In simplistic terms, reinvestment in TDEF of £100,000 year-on-year from operating margins from each of ten 2.1MW turbines would generate approximately 2.7 billion averted/sequestered tCO_2e over a century that, with substantial uncertainties, more or less equates to the emissions of the population of south-west England in the coming century.

Extending these broad approximations further – perhaps heroically as many more uncertainties are introduced but nevertheless serving to illustrate possibilities – the 70 million people of the UK (approximately 65 million today rising to 75 million by 2050) would emit 406 million $tCO_2e\ year^{-1}$, assuming the same mean per capita carbon dioxide emissions of 5.8 $tCO_2e\ year^{-1}$. Over a century, this would result in cumulative UK carbon dioxide emissions of 40.6 billion tCO_2e, once again overlooking population, per capita emission and other trends. In purely illustrative terms, this total averted/sequestered CO_2e could be achieved under the TCW model by investment in one hundred and fifty wind turbines in Tamil Nadu with year-on-year reinvestment in TDEF restoration, accounting for 40.6 billion tCO_2e hypothetically averted/sequestered over a century whilst simultaneously generating substantial renewable electricity aiding Indian aspirations to achieve a low-carbon pathway of development.

Extrapolating considerations from city region to national region to whole-country scales introduces cumulatively greater uncertainties that render conclusions increasingly unreliable. Interim conclusions are nevertheless indicative of potential co-benefits from investment in the developed-developing world partnership, though requiring further development to produce a more robust business case. However, commitments to curtailing climate-active gas emissions apply not merely to municipalities, but also at institutional and individual levels.

Institutional level may include a business, a university, a hospital, a council, a government office or department, a large club or social enterprise or any of a range of organisations with significant carbon emissions. The University of the West of England (UWE), a higher education institution based in Bristol for which published CO_2e emissions data are published. It is therefore used for demonstration purposes as an institution with potential interests in 'buying' CO_2e 'offsets'. In the academic year August 2014 to July 2015, UWE comprised 27,750 people emitting 81,311 tCO_2e, an average of approximately 2.9 tCO_2e per person (see Box 3). Overlooking likely fluctuations in numbers of people and per capita emissions relative to 2014/15 data, cumulative UWE emissions of carbon dioxide over a century would equal approximately 8 million tCO_2e (8,131,000 tCO_2e). Extending the logic applied to Bristol City above, UWE's century-long total CO_2e emissions could be addressed by an up-front investment of approximately £47,000 (£47,335:39: see Box 3). This

represents a 3% contribution to the £1,575,000 cost of commissioning a new 2.1MW wind turbine in Tamil Nadu, potentially a cost-effective and transparent means for this type of institution to address its commitments as large emitters of climate-active gases, with the added advantage of taking the form of a one-off up-front payment rather than a recurring annual charge.

Box 3: Population and CO_2e emissions at UWE, academic year 2014-2015

People at UWE = 27,750 (UWE, 2016a), comprising:

- 3,068 part-time students (6,136 assumed to be present half-time)
- 21,144 full-time students
- 3,538 staff

Annual CO_2 emissions at UWE = 81,311 tCO_2e (UWE, 2016b) comprising:

- 16,753 tCO_2e: Scope 1 (burning of fuels on site) + Scope 2 (emissions associated with purchased energy
- 64,558 tCO_2e: Scope 3 (indirect emissions out of direct UWE control including transport including commuting, water, sewage, waste, construction and procurement of goods and services including construction)

Per capita annual emissions for people in UWE activities (excluding lifestyle) ≈ 2.9 tCO_2/person

- 81,311 tCO_2e ÷ 27,750 people = 2.930 tCO_2e/person

Cumulative carbon dioxide emissions over a century, assuming 2014/15 emissions are maintained (overlooking likely fluctuations in numbers of people and per capita emissions) = 8,131,100 tCO_2e, accounted for by:

- 100 x annual emission of 81,311 tCO_2e

Illustrative up-front cost to UWE of 'offsetting' century-long carbon dioxide emissions by investment in wind turbine installation under the TCW model ≈ £47,000 (£47,335:39), comprising:

- £1,575,000 upfront cost of 2.1MW wind turbine implementation in Tamil Nadu assuming year-on-year reinvestment in TDEF over 20 years operational life consistent with the TCW model, multiplied by
- 8,13,100 (century-long UWE tCO_2e emissions) ÷ 270,627,756 (century-long tCO_2e averted/sequestered under the TCW model)

Individuals too may have any of a range of reasons for wanting to invest transparently in global climate change ecosystem services. This may include, for example, taking personal responsibility, wishing to 'switch off' the carbon contributions of a descendent over their lifetime through a certificated contributory loan for investment in a turbine, or other generally altruistic arguments. Assuming a 70-year lifespan at the Bristol City average emission of 5.8 tCO_2e per annum, average personal lifetime emissions in the developed world region would be 406 tCO_2e. On the basis of year-on-year reinvestment of renewable energy revenues into TDEF eco-restoration in the TCW model, this lifetime emission would represent 406/270,627,756 of the net CO_2e averted/sequestered benefit, and therefore the

same proportion of the cost of up-front turbine implementation (£1,575,000). This calculation yields an up-front investment value of approximately £2.36 to account for 'offsetting' the lifetime emissions of a person born into Bristol or similar settings.

This type of market is a genuinely co-beneficial between partner developed-developing world regions. The TCW model is based on seeking optimally efficient gross carbon averting/sequestering processes as part of a notional conjoined Tamil Nadu/south-west England 'nation', achieved at lower cost compared with installing or restoring similar infrastructure within the developed world region. However, the introduction of renewable energy into the Indian grid, promotion of a pathway of lower-carbon development, sequestration of carbon in TDEF and the wider suite of ecosystem service benefits and contributions to ecosystem functioning produced by both wind turbine generation and restored TDEF can enhance the security and wellbeing of a diversity of people in Tami Nadu state. The 'multiplier effect' of reinvestment in TDEF eco-restoration does not merely amplify overall carbon abatement (99.97% of the overall total tCO_2e benefit) but also generates multiple pro-poor development through additional ecosystem service benefits ranging from provision of forest-based food, fibre and medicinal resources, stabilisation of water and soil resources, enhancement of sites and landscapes of spiritual, traditional and other cultural benefits, and enhanced ecosystem functioning through regeneration of biodiversity and enhancement of the overall resilience of the bioregion.

These up-front cash contributions could take the form of loans rather than payments, for example constituting 'zero carbon fund' loans taken out in the name of an individual, institution or cause. At maturation of the investment period (recalling the operational/depreciation lifetime of a wind turbine), the cash can be returned to the named beneficiary. Alternatively, the loan may be reinvested into new schemes with the same set of linked ecosystem service benefits, or else cancelled. No conclusions are drawn about optimal financial models.

Valuation of ecosystem service co-benefits

In addition to the 'anchor service' of global climate regulation, Everard *et al*. (submitted) and Everard (2015a) also identify a diversity of potential benefits arising from measures in the TCW programme, particularly those stemming from habitat restoration. There benefits span direct benefits in the form of provisioning, regulatory and cultural and indirect contributions to benefits in the form of functions classified by the Millennium Ecosystem Assessment as supporting services. Valuation of the diversity of ecosystem service co-benefits is clearly important not merely as they augment the already compelling case for investment in linked renewable energy generation and habitat restoration, but also because it is important that this diversity of benefits and the functions that secure them are recognised and weighted in decision-making if externalities are to be avoided. Recognition of the multiplicity of benefits – those that can be more readily quantified and monetised but also those that are more deeply held and less readily measured and valued financially or contributory to other direct benefits – is important for engaging all interests in society in collectively beneficial interventions. Services of particular significance to some stakeholders, for example inherently non-monetisable services of spiritual or other cultural significance, may make a compelling case for sectors of

local society to engage, or to accept management action as active players, in landscape management.

Discussion

The economic case developed in this paper revolves primarily around the 'anchor service' global climate regulation within the TCW developed-developing world partnership model of low-carbon development and linked eco-restoration, assisting both south-west England and Tamil Nadu on a low-carbon transition in a cost-efficient way. The 'multiplier effect' of reinvestment of a proportion of revenues from renewable energy generation into habitat restoration makes a substantial contribution (99.97%) to overall lifetime tCO_2e averted/sequestered, with significant implications for the cost-effectiveness of global climate regulation. Values calculated are tentative at only £0.0058 £ per tCO_2e ($US0.01 per tCO_2e), given the sparse data and broad assumptions used in calculations. They are nevertheless indicative of the scale of benefits arising from the TCW developed-developing world partnership model for low-carbon development. Compared with other mechanisms for pricing carbon and their inherent volatility (for example see Box 4), CO_2e averted/sequestered through investment in linked TDEF renewable generation and eco-restoration is highly cost-efficient from a carbon perspective alone.

Box 4: Example mechanisms for pricing carbon emissions and abatement

The following are examples of formalised methods for pricing carbon emissions and abatement:

- 'Social cost of carbon' (SCC) of approximately £20/tCO_2e (Defra, 2007);
- 'Shadow price of carbon' (SPC) of around £25/tCO_2e (Defra, 2007);
- 'Marginal abatement cost' (MAC) reflecting the cost of reducing emissions;
- The UK's 'carbon floor price' at around £16/tCO_2e (HM Treasury and HMRC, 2010); and
- The EU carbon price of around €5/tCO_2e (Carbon TradeXchange, 2015).

However, a further important consideration is that the financial values generated in this study, illustrative as they are, only relate to the 'anchor service' of global climate regulation. The linked set of co-beneficial ecosystem services and functions characterised qualitatively by Everard *et al*. (submitted) and Everard (2015a) are diverse and significant for a range of stakeholder groups, contributing to important aims such as addressing all 17 of the UN Sustainable Development Goals. Recognition of this multiplicity of linked ecosystem service co-benefits therefore has cumulative significance for the overall social return on investment (SROI) in the TCW partnership programme. Many ecosystem service studies fail to address more deeply held values less readily elucidated by conventional survey techniques (Kenter *et al*., 2015) as well as cultural services that may contribute significantly to scheme success and net societal benefit (Tengberg *et al*., 2012). Key messages arising from community and livelihood aspects of Millennium Ecosystem Assessment sub-global assessments (Folke *et al*., 2005) emphasise that local communities are not mere spectators, but are active participants in and managers of ecosystems and their

capacities to deliver services. Diversity in ecosystems is important in reducing the vulnerability of communities. Ecosystem services with spiritual and cultural values arising from them may be as important as more immediately exploitable services for many local communities, providing a sense of place and identity, aesthetic and recreational values. The global poor are often the most disadvantaged by decisions founded on the narrow, often commercial priorities of privileged sectors of society, yet these less readily deduced, non-commercial ecosystem service values with local meaning are nevertheless integral to formation and maintenance of 'cultural landscapes' characterised by biodiversity and ecosystem services shaped by a complex, extended history of settlement and land use (Antrop, 1997 and 2005; Jones-Walters, 2008; Schaich *et al*., 2010). Further research is required to quantify, and ideally to monetise or capture in other non-monetary means, the diversity of potential ecosystem service co-benefits generated by restored TDEF.

The focus of benefit assessment from habitat restoration in this paper has been on TDEF, the priority degraded, locally representative forest type that has been the initial focus for TCW/Pitchandikulam Forest and Bio-Resource Centre restoration efforts. However, the water system in the catchments in which these forests currently lie, or formerly lay, is of particular importance not merely due to its close interaction with forestry but as it is a major contributor to the vitality of ecosystems of inherent worth and also supporting a diversity of human needs including poverty alleviation. Sustainable water management is a priority for Tamil Nadu as the climate ranges from dry sub-humid to semi-arid, the greater part of the state falling under the 'Tropical savanna climate' category with a smaller proportion of the state falling under the 'Humid subtropical climate' category under the Köppen climate classification (Köppen and Wegener, 1924). Tamil Nadu is heavily dependent on monsoon rains, and is prone therefore to droughts when monsoons fail as well as severe episodic floods (as for example catastrophic flooding in Chennai in November/December 2015: Sandhu, 2015). The Kaliveli system in which the Nadukuppam forest area is situated, as is part of the long-restored Pitchandikulam Forest on the Auroville Plateau, is a water-driven ecosystem with substantial ecological and livelihood support importance. The Kaliveli system spans an area of 740 km^2 (74,000 ha) including at its coastal end linked creeks, floodplain, mudflat, mangroves and estuary important for ecological and livelihood purposes. Direct restoration of these functional habitats, and of the currently degraded hilltops and hill slopes, wetlands and tanks contributing to the functioning of the wider catchment, all represent potential priorities for restoration with a host of climate regulation, water security, ecological, livelihood support and other linked ecosystem service benefits. Tamil Nadu's tank systems' local adaptations to achieving water security in this semi-arid region of episodic water availability, have suffered the same kinds of long-term decline in quality, extent and loss of traditional collaborative management as witnessed across much of the rest of India and indeed the tropical world (Everard, 2015b), as mechanised pumping technologies have both depressed groundwater levels and suppressing incentives for community-based management of common water capture technologies that have persisted for centuries as an adaptation to local conditions (Bardhan, 2000; Kajisa *et al*., 2004). Rehabilitation of traditional groundwater recharge and other water harvesting techniques and the social infrastructure that supports them, including effective community-level agreements to avert symmetric access to groundwater resources that deprives others, is a necessary condition for the recovery of ecosystems and intimately linked socio-

economic security and progress (Palanisami, 2000; Everard, 2013). Given the critical role of water in arid and semi-arid environments, water management will have many additional co-benefits. Threats to poverty and equity arising from the decline in collective tank irrigation management have been identified as a particular threat in Tamil Nadu (Kajisa, 2007). Characterising ecosystem service contributions from a range of regional habitat types, and prioritising restoration opportunities on the basis of optimal benefit realisation, would be a useful focus for further research, optimising the societal benefits of reinvestment beyond the initial focus on TDEF.

A further research need is identify means to secure the benefits of CO_2e averted/sequestered and other linked ecosystem services in perpetuity ('ensure permanence' in the PES-related principles summarised in Box 1). The current TCW model is to vest ownership of land purchased for eco-restoration in Indian Trusts. Ownership of Nadukuppam Forest is by the Kaluveli Environment Education Trust (KEET) with Trustees comprising a range of local community and other representatives directing matters consistently with the inter-regional partnership. Loan payments made up front to enable installation of wind turbines can be repaid to named holders at the conclusion of their term, reinvested to achieve further societally beneficial outcomes, or surrendered effectively to remove sequestered/averted carbon from the market. There are administrative efficiencies entailed in this form of up-front investment, relative to annual payments.

The investment model, though market-based, is founded on a different kind of economic paradigm to the established norm of investment primarily for private profit-generation. It seeks instead to deliver SROI founded initially on the 'anchor service' of climate regulation but acknowledging scope for future markets based on other ecosystem services. The initial phase of TCW investment in wind turbines has relied on bank loans at commercial rates, limiting surplus funds available for reinvestment in TDEF eco-restoration and other elements of the TCW programme of support for regional development. TCW's aspiration is to migrate investment to a more substantial extent on zero-interest or low-interest loans, and possibly also grants, that are offered with the aim of generating profit not simply in terms of private profit but as SROI focusing on public benefit. This model of SROI forming the primary interest on loans – benefits arising to society as a form of 'collateral virtue' rather than narrow maximisation of personal financial returns achieved often by means generating uncounted 'collateral damage' – harks back to the origins of money as a medium of exchange of skills and goods as society first differentiated roles as settled civilisations were founded (Everard, 2011). Money was a social connector, enabling the creation of benefits rather than serving the more contemporary purpose of accumulating personal wealth, and later corporate wealth, on a competitive basis. This contemporary competitive model often results in international loans from developed-world interests to developing nations that result in poorer nations battling against mounting interest, the developing world effectively subsidising richer interests that have assets to spare and invest (Shah, 2007). Eisenstein (2011) highlights how, for the investor in the modern competitive model, profit no longer bears the 'history' of social and environmental implications entailed in its generation, within an essentially amoral market economy only partially constrained by regulation but still largely failing to account for its consequences for the long-term wellbeing of supporting ecosystems and distributional impacts on people. Eisenstein (2007) posits a different sort of 'sacred economics', harking back to historic 'gift economies',

recognising how money can and should be used to help people address needs across society. The 'sacred economics' approach is envisaged as a driving force in the transition to a more connected, ecological and sustainable model in which outcomes are measured not in terms of personal wealth accumulation, founded on little more than usury, but instead in societal enrichment and ecological resilience. The idea of loans that do not repay in narrow financial terms, or that do so only at a low rate, but which generate public and ecological benefits as priority returns are underpinning aspirations of the TCW programme. In the light of the substantial, tangible and transparent contributions of the TCW programme to cost-effective carbon management, and potentially to a range of connected though currently unquantified ecosystem service co-benefits of direct relevance to addressing high-profile targets such as the UN Sustainable Development Goals, these loans are clearly far more than altruistic. The potential investor community – corporate, government, institutional, donor, private or other – has evidence of a wide spectrum of ecosystem service benefit delivery through this linked development-developing world partnership programme.

Conclusions

- The TCW model represents a robust, cost-effective and efficient developed-developing world partnership approach to addressing global climate change goals in a mutually beneficial way between partner regions, incorporating a substantial 'multiplier effect' through reinvestment of operating surpluses from renewable energy generated by wind turbines into restoration of tropical dry evergreen forest (TDEF).

- The 20-year operating life of a 2.1MW wind turbine in Tamil Nadu may avert 80,000 tCO_2e compared to equivalent generation using India's conventional energy mix, but annual reinvestment of £100,000 of operating surpluses into TDEF restoration can generate 123 ha of new forest sequestering 270,547,725 tCO_2 as it progresses to climax community. Averted carbon from renewable energy sales account for just 0.03% of total CO2e averted/sequestered.

- This represents a highly efficient means to address climate change, with a theoretical cost per unit tCO_2e sequestered/averted – admittedly based on sparse source data and hence with significant uncertainties – of £0.0058 £ per tCO_2e (≈ $US0.01 per tCO_2e).

- Applying these values to the English statutory unitary authority area of Bristol City and County of Bristol, cumulative city-wide CO_2e emissions over the coming century, assuming unchanged population and per capita emissions, would total 256,550,000 tCO_2e over a century. In simplistic terms, this approximates to the 270,627,756 tCO_2e lifetime averted/sequestered CO_2e achieved from the sum of renewable electricity generated and annual reinvestment in TDEF eco-restoration from a single 2.1MW wind turbine in Tamil Nadu. This could represent one-off investment in an initial year of £3:56 for each of Bristol City's 442,500 population.

- Similar calculation apply at institutional level. The University of the West of England (UWE), a higher education institution based in Bristol with published CO_2e emissions, is used as a case study of an institution with carbon management commitments as a large emitter of climate-active gases. Overlooking likely fluctuations in numbers of people and per capita emissions relative to 2014/15 data, cumulative UWE emissions of over a century would equal approximately 8 million tCO_2e, which could be matched by an up-front investment of approximately £47,000 representing a 3% contribution to the £1,575,000 cost of commissioning a new 2.1MW wind turbine in Tamil Nadu. This has the added management advantage of being a one-off, up-front payment rather than a recurring annual charge.

- These illustrative financial values relate only to the 'anchor service' of global climate regulation. However, the diverse linked set of co-beneficial ecosystem services, principally from TDEF restoration, are significant for a range of stakeholder groups and also make contributions to addressing all 17 of the UN Sustainable Development Goals. As local communities are active participants in and managers of ecosystems and their capacities to deliver services within 'cultural landscapes', further research is required to value this diversity of societal co-benefits.

- TDEF is just one of a range of degraded bioregional habitat types that can deliver a range of ecosystem services, including climate regulation but also significantly regenerating the water system of the Kaliveli catchment.

- The desired investment model, once initial traditional banking loans are repaid, regards social return on investment (SROI) as the primary form of interest rather than the simple maximisation of financial profit to investors.

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