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OPTIONS FOR COOPERATIVE ACTION IN THE EUPHRATES AND TIGRIS REGION

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List of Abbreviations

AQUASTAT	FAO's Global Information System on Water and Agriculture
BCM	Billion Cubic Meters
ET	Euphrates and Tigris
GADM	Database of Global Administrative Areas
GIS	Geographic Information System
HPP	Hydropower Production
IPCC	Intergovernmental Panel on Climate Change
LocClim	FAO Local Climate Estimator
MCM	Million Cubic Meters
NASA	National Aeronautics and Space Administration
RO	Runoff
Sida	Swedish International Development Cooperation Agency
SRTM	Shuttle Radar Topography Mission
USD	United States Dollar
WUE	Water Use Efficiency
WorldClim	Global Climate Data
WWW	World Water Week

Glossary

Ecosystem goods and services
Resources and processes that are supplied by natural ecosystems. Examples include water purification provided by wetlands and nutrient cycling.

Hydroeconomic model
Model that links economic values to hydrological flows and uses.

Marginal benefit
The additional benefit received by one unit increase in inputs.

Minimum flow requirement
The minimum water flow required to keep aquatic ecosystems healthy.

Multiplier effect
The indirect effects on the level of economic activity (output, income or employment), associated with a policy intervention (e.g. where the hydropower generated is used for industrial development, which results in an increase of the gross domestic product (GDP)). The size of the multiplier depends on the time period over which it is measured, and the geographical area considered.

Shadow value
The value of the resource in an alternative use.

Public good
A good which can be consumed by several individuals simultaneously and from which no individual is excluded. In economic terms, public goods are non-rivalrous and non-excludable. Examples include public parks and air quality.

Water use efficiency (WUE)
An indicator of the amount of water used to produce one unit of output.

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1. Executive Summary

For the Euphrates and Tigris (ET) riparian countries of Iran, Iraq, Syria and Turkey we have undertaken a macro-level baseline characterisation to visualise current water resources management practices and a hydroeconomic simulation model to illustrate possible marginal benefits of cooperative action at a system level. The riparian countries in the ET region are connected by the water resources flowing across borders within one system.

The study only used publicly available and remote sensing data thus providing a common starting point for all stakeholders to access the same information. In addition the study was supported by a reference group comprised of representatives and observers from governments and regional institutions. As part of the dialogue, the representatives and observers were asked to present examples of hotspots that have a regional dimension. The target audience and direct beneficiaries of the study are policy makers in the ET region.

The study's hypothesis is that options exist to generate marginal benefits from a cooperative approach to water resource management and development and that presently the water resources are managed sub-optimally from a regional perspective. A cooperative approach to managing the water resources is necessary to secure future benefits from the water resources and to maintain peace, stability and support socio-economic development in the region. To test the hypothesis, the study designed a basic Excel based hydroeconomic simulation model, treating the basin as one unit and delineating 13 sub-basins. The model focuses on water use for hydropower, irrigated agriculture and environmental flows and provides a macro-perspective on water use challenges and opportunities. Water use efficiency (WUE) improvements in irrigated agriculture were modelled as the main driver for water saving in the 13 sub-basins. The model places the saved water in monetary terms by looking at the value of use in hydropower and irrigated agriculture. While the market and non-market benefits of environmental flows were not estimated as part of this study, the shadow value of environmental flows are estimated to represent the cost of diverting the saved water from other productive uses in the sub-basins.

Using average market prices across the ET region, the baseline hydropower and irrigated agriculture values are USD 3.5 billion and USD 4.8 billion per annum respectively. Using the hydroeconomic model, simulations were performed and illustrate that with saved water resulting from a 30 percent irrigated agriculture WUE improvement in all sub-basins; the value of the marginal benefits could range from USD 200 million to USD 1.45 billion, depending on the scenarios. The values can be distributed across additional hydropower and irrigated agriculture, although as the model is presently calibrated, using the saved water for irrigated agriculture presents the highest values. The model does not look at an expansion of hydropower dams – it only takes into account the use of saved water within the existing facilities. Shadow values for different volumes of saved water for environmental flow can range from USD 286 million to USD 515 million, depending on the scenarios. All values are based on average market prices and do not take the multiplier effects into account. If the saved water generated from WUE improvements in irrigated agriculture is to be used to support environmental flows, it has a relatively low shadow value when compared to irrigated agriculture.

The study verifies that that ET system is currently under significant pressure resulting in water quality degradation within the system and externality impacts beyond the system, such as haze and dust storms with significant negative impacts to the economies in the neighbouring region. The system is heavily regulated from a water resources point of view which can provide options for rethinking current water management and development practices. The potential productive uses of saved water are significant and could be conjunctively managed across the sub-basins for a range of productive uses including hydropower, irrigated agriculture, salinity management, wetlands and sea coast ecosystem goods and services.

The study confirmed that there is significant opportunity to improve irrigated agriculture WUE and to use the saved water to increase agricultural yields in the sub-basins and/or increase hydropower production (non-consumptive use of water) and allocate water to environmental flow and restoration of ecosystem goods and services (consumptive use of water). However, this comes with a caveat: with little knowledge on the exact sources of inefficiency of agricultural water use, i.e. at farm level within each sub-basin, choice of crops, irrigation canals, drainage systems; supporting additional irrigated agriculture in the sub-basins with saved water will need further detailed work to identify the correct management choices. The ET region is naturally vulnerable to salinity problems and there is a trend of increased salinity, impacting on the functioning of the aquatic ecosystems and on agricultural yields. Without appropriate measures to address and mitigate salinity, encouraging further expansion in agricultural activity at present levels of efficiency, will exacerbate the problem.

Cooperative options that could be further explored in subsequent collaborative work include a range of activities stemming from institutional issues, capacity building and investments across the short, medium and long term.

الملخص التنفيذي

يقدم هذا البحث عدداً من العوائد الإقتصادية المتوقعة كنتيجة هامشية للتعاون المشترك الذي تقترحه الدراسة ما بين دول حوض نهري دجلة والفرات (إيران، العراق، سورية، وتركيا) في مجال الإدارة المتكاملة للموارد المائية، وذلك بناءً علىتحليل للممارسات الحالية على مستوى الحوض، وسيناريوهات تنمية هيدرولوجية تعتمد على مبدأ تشارك العوائد الاقتصادية على مستوى النظام الكلي. يمكن لنتائج هذة الدراسة أن تمثل الركائز الأساسية لتعزيز الحوار في المستقبليين الذين يبحثون عن الخيارات التعاونية لإدارة المياه والتدفقات الاقتصادية الأخرى في منطقة دجلة والفرات، و يمكن التوسع في بحث هذة العلاقة في عمل مشترك لاحق.

اعتمدنا في هذا البحث على البيانات المتاحة علناً وبيانات الاستشعار عن بعد (بواسطة الأقمار الصناعية) مما يوفر سهولة الوصول إلى هذه المعلومات لاحقاً لمن يرغب في ذلك، وبالإضافة إلى ذلك دعمت هذه الدراسة مجموعة مرجعيةتتألف من ممثلين ومراقبين من الحكومات والمؤسسات الإقليمية و قدموا لتعزيزها أمثلة أقليمية واقعية للتواصل مع الجمهور المستهدف من هذه الدراسة و هم واضعي السياسات ومتخذي القرارات في المنطقة وافادتهم بشكل مباشر.

فرضيتنا الأساسية في هذا البحث هي وجود خيارات فعلية لتحقيق العوائد الإقتصادية كنتيجة للتعاون المشترك في إدارة و تنمية الموارد المائية على مستوى الحوض، وأنه من المنظور الإقليمي تدار الموارد المائية حالياً على نحو أقل منأمثل. لابد من التعاون لإدارة الموارد المائية و ذلك لتأمين الأنتفاع من هذه الموارد في المستقبل وأيضاً للحفاظ على السلام والاستقرار ودعم التنمية الاجتماعية والاقتصادية في المنطقة. و لنختبر صحة هذه الفرضية صممنا نموذج محاكاةمبني على أسس التنمية الهيدرولوجية و قسمنا في هذا النموذج حوض النهرين إلى ثلاثة عشر أحواض فرعية، و يركز هذا النموذج على استخدام المياه لتوليد الطاقة الكهرومائية والزراعة المروية والتدفقات البيئية مما يمثل رؤية شاملةلتحديات و فرص استخدام المياه. المحرك الرئيسي لهذا النموذج هو توفير المياه من خلال تحسين كفاءة استخدامها في الزراعة المروية، و من خلال نموذجنا استطعنا أن نقدر كمية المياه التي يمكن توفيرها تقديراً مالياً و ذلك بحسابقيمة استخدامها في توليد الطاقة الكهرومائية والزراعة المروية، في حين أننا لم نقدر فوائد التدفقات البيئية من توفير هذه المياه (سواء داخل السوق أو خارجه)، فإن القيمة الوهمية للتدفقات البيئية تقدر بتكلفة تحويل مجرى المياه التي يتمتوفيرها من استخداماتها الانتاجية الأخرى في الأحواض الفرعية.

حسب متوسط أسعار السوق في منطقة دجلة والفرات، فإن القيم الأساسية لتوليد الطاقة الكهرومائية و الزراعة المروية ٣،٥ و ٤،٨ مليار دولار أمريكي سنويا على التوالي، لكننا أثبتنا من خلال النموذج و عمليات المحاكاة في هذا البحث أنقيمة الفوائد الهامشية الناتجة عن توفيرالمياه مع تحسين ٣٠ ٪ من خلال كفاءة استخدام المياه في الزراعة المروية في الأحواض الفرعية قد تتراوح بين ٢٠٠ مليون و ١،٤٥ مليار دولار أمريكي و ذلك وفقاً لسيناريوهات مختلفة. النموذجبشكله الحالي يشير إلى أن باستخدام المياه التي يتم توفيرها في الزراعة المروية تتحقق أعلى القيم و لكن من الممكن توزيع هذه القيم عبر استخدامات إضافية في توليد الطاقة الكهرومائية والزراعة المروية، فنحن نعتمد في هذا النموذجعلى استخدام المياه المحفوظة داخل المنشآت القائمة حالياً و ليس التوسعات المستقبلية في بناء السدود المائية. وتستند جميع القيم على متوسط أسعار السوق و ليس الآثار المضاعفة. وقد تتراوح القيم الوهمية للمياه التي يتمتوفيرها لأغراض بيئية بين ٢٨٦ و ٥١٥ مليون دولار أمريكي و ذلك وفقاً لسيناريوهات مختلفة، اذا تم استخدام المياه الموفرة عن تحسينات كفاءة استخدام المياه في الزراعة المروية لدعم التدفقات البيئية فإن قيمتها الوهمية تنخفض نسبياًبالمقارنة مع حالة استخدامها في الزراعة المروي.

يؤكد البحث أن منطقة دجلة والفرات تتعرض حالياً لضغط هائل مما أدى إلى تدهور جودة المياه بداخلها بل و تمتد آثار هذا الضغط لخارج المنطقة و تؤدي على سبيل المثال إلى عواصف الضباب والغبار مما يؤثر بالسلب على اقتصاد الدولالمجاورة. إن منطقة دجلة والفرات تُنظم و بشكل كبير من خلال منظور الموارد المائية مما يتيح الخيارات لإعادة التفكير الحالي في إدارة المياه وممارسات التنمية، فللاستخدامات الممكنة للمياه المُوفرة في المجال الإنتاج تأثير كبير علىالمنطقة ويمكن إدارتها بالتعاون عبر الأحواض الفرعية في استخدامات انتاجية عديدة كتوليد الطاقة المائية والزراعة المروية وإدارة الملوحة والأراضي الرطبة و البضائع والخدمات الايكولوجية الساحلية.

خلاصه اجرایی

برای به تصویر کشیدن روشهای کنونی مدیریت منابع آب در کشورهای ساحلی رودخانه های دجله و فرات (ایران، عراق، سوریه، و ترکیه) و برای تشریح منافع نهایی بالقوه همکاری در سطح سیستم، یک مطالعه مبنا در مقیاس کلان و یک شبیه سازی هیدرو-اکونومیک انجام داده یم. کشورهای حوزه دجله و فرات به واسطه عبور منابع آبی از مرزهایشان در چارچوب یک سیستم واحد با هم مرتبطند. نهادهایی که برای مدیریت آب و جریان های اقتصادی دیگر در حوزه دجله و فرات به دنبال همکاری هستند می‌توانند از نتایج این مطالعه به عنوان بستری برای گفتگوهای آتی استفاده کنند. این نتایج می تواند در مطالعات مشترک بعدی مورد کاوش بیشتر قرار گیرد.

به عنوان نقطه شروعی برای دسترسی کلیه ذینفعان به اطلاعات یکسان، در این مطالعه تنها از داده هایی که در دسترس عموم قرار دارند و یا از داده های سنجش از دور استفاده شده است. به علاوه ، مشارکت یک گروه مرجع متشکل از نمایندگان و ناظرانی از سوی دولتها و نهادهای منطقه ای به این مطالعه کمک می کند. به عنوان بخشی از گفتگو، از این نمایندگان و ناظران خواسته شد تا مثالهایی از نقاط حساسی که از اهمیت منطقه ای برخوردارند ارائه دهند. مخاطبین و ذینفعان مستقیم این مطالعه سیاست گذاران حوزه دجله و فرات هستند.

فرضیه این مطالعه اینست که بر پایه همکاری و مشارکت کشورها در مدیریت و توسعه منابع آب، گزینه هایی جهت ایجاد منافع نهایی وجود دارد و اینکه مدیریت منابع آب در در حوزه دجله و فرات در حال حاضر از نقطه نظر منطقه ای پائین تر از سطح بهینه صورت می گیرد. از این‌رو، برای تامین منافع حاصل از منابع آب در آینده و حفظ صلح، ثبات و حمایت از توسعه اجتماعی-اقتصادی در منطقه، استفاده از یک رویکرد مبتنی برهمکاری و مشارکت کشورها در مدیریت منابع آب ضرورت دارد. برای آزمایش این فرضیه، در این مطالعه یک مدل مقدماتی شبیه سازی هیدرو-اکونومیک در محیط اکسل طراحی شده است که در آن حوزه دجله و فرات به صورت یک واحدحاوی ۱۳ زیر حوزه شبیه سازی می شود. این مدل بر استفاده از آب برای تولید انرژی برقابی، تامین آب جهت مصارف کشاورزی و تامین آب لازم برای مصارف زیست محیطی تمرکز دارد و چشم‌اندازی کلان از چالشهای مصارف آب و فرصتها ارائه می دهد. بهبود بازده مصرف آب در آبیاری محصولات کشاورزی به عنوان یک عامل عمده صرفه جویی آب در این ۱۳ زیر حوزه شبیه سازی گردیده است. این مدل ارزش پولی آب صرفه جویی شده را بر اساس ارزش اقتصادی استفاده از آب برای تولید انرژی برقابی و محصولات کشاورزی تعیین می کند. اگرچه منافع بازاری و غیر بازاری جریان زیست محیطی در چارچوب این مطالعه برآورد نشده، با وجود این، برای نشان دادن هزینه عدم استفاده از آب ذخیره‌شده جهت مصارف مفید و مولد در زیر حوزه ها ، ارزش سایه‌ای جریان زیست محیطی تخمین زده شده است.

براساس میانگین قیمت‌های بازار در سطح منطقه دجله و فرات، ارزش پایه سالانه انرژی برقابی و کشاورزی آبی به ترتیب ۳,۵ و ۴,۸ میلیارد دلار امریکا برآورد شده است. شبیه‌سازی‌های مدل هیدرو-اکونومیک نشان می‌دهد که منافع نهایی آب صرفه جویی شده حاصل از بهبود ۳۰ درصدی بازده مصرف آب در تمام زیر حوزه‌ها، می‌تواند ارزشی معادل ۲۰۰ میلیون تا ۱,۴۵ میلیارد دلار امریکا داشته باشد که این مقادیر بسته به سناریو مورد استفاده متغیر است. اگرچه بر اساس تنظیمات فعلی مدل، تخصیص آب ذخیره شده به کشاورزی آبی بالاترین ارزش را به دست می‌دهد، اما مقادیر فوق می‌تواند جهت تولید انرژی برقابی و محصولات کشاورزی آبی بیشتر، توزیع شود. مدل حاضر گسترش سدها برای تولید انرزی برقابی را در بر نمی‌گیرد و تنها استفاده از آب صرفه جویی شده در تاسیسات موجود را مورد ملاحظه قرار می‌دهد. ارزش سایه‌ای حجم‌های مختلف آب ذخیره‌شده مصرفی برای مقاصد زیست محیطی، بسته به و ٥١٥میلیون دلار امریکا متغیر است. تمامی مقادیر حاضر بر اساس میانگین سناریو مورد استفاده، بین ٢٨٦ قیمت‌های بازار هستند و تاثیر ضرایب فزاینده (وابسته به عوامل خارجی) در نظر گرفته نشده است. قابل توجه است که ارزش سایه‌ای استفاده ازآب صرفه جویی شده حاصل از بهبود بازده آب مصرفی در کشاورزی آبی برای تامین جریان‌های زیست محیطی، کمتر از ارزش سایه‌ای آن درکشاورزی آبی است.

این مطالعه فشار بسیارزیاد موجود بر روی سیستم دجله و فرات و اثرات ناشی از آن مانند افت کیفیت آب در داخل سیستم و تاثیرات خارجی فراتر همچون طوفان گرد و غبار با اثرات منفی قابل توجه بر اقتصاد مناطق همجوار را تایید

Özet

Bu çalışmada, Fırat ve Dicle (FD) nehirlerine kıyısı bulunan İran, Irak, Suriye ve Türkiye için mevcut su kaynakları yönetimi uygulamalarını değerlendiren, makro düzeyde bir ana hat karakterizasyonu ve havza düzeyinde işbirliğinin faydalarını açıklayacak bir hidroekonomik simülasyon modeli oluşturmayı üstlendik. Bu çalışma, Firat ve Dicle gibi sınıraşan suları barından havza içerisinde, su yönetimi ve ekonomik işbirliği seçeneklerini arayanlar arasında gelecekteki diyalogların temelini oluşturacak bir platform işlevi görebilir.

Araştırmada yalnızca kamuya açık olarak ulaşılabilecek ve uzaktan algılama verileri kullanılmıştır. Böylece aynı bilgilere erişmede tüm ilgililer için ortak bir başlangıç noktası sağlanmıştır. Ayrıca araştırma ilgili hükümetler ve bölgesel kuruluşlardan temsilciler ve gözetmenlerden oluşan bir referans grubu tarafından desteklenmiştir. Diyalogun bir parçası olarak temsilciler ve gözetmenlerden bölgesel boyutu olan örnek sıcak noktaları sunmaları istenmiştir. Araştırmanın hedef kitlesi ve doğrudan faydalananlar FD bölgesinin yönetimleri ve/veya ilgili kuruluşlarıdır.

Araştırmanın hipotezi, su kaynaklarının yönetimi ve geliştirilmesi işbirliğine dayalı bir yaklaşımdan marjinal faydalar üretme seçeneklerinin var olduğu ve halen su kaynaklarının bölgesel bir perspektiften yetersiz olarak yönetildiğidir. Bölgede su kaynaklarından gelecekte elde edilecek faydaları güvence altına almak, barış ve istikrarı sürdürmek ve sosyoekonomik gelişimi desteklemek için su kaynaklarının yönetilmesinde işbirliğine dayalı bir yaklaşım gereklidir. Hipotezi sınamak amacıyla araştırmada havzayı bir birim olarak ele alan ve 13 alt havzayı nitelendiren, temel bir Excel tabanlı hidroekonomik simülasyon modeli tasarlanmıştır. Model hidrogüç, sulu tarım ve doğal hayat su ihtiyacı için kullanımına odaklanmakta ve su kullanımının zorlukları ve fırsatlarına makro bir perspektif sağlamaktadır. Sulu tarımda su kullanımı verimliliği (SKV) iyileştirmeleri 13 alt havzada su tasarrufu için ana sürücü olarak modellenmiştir. Model, hidrogüç ve sulu tarımda kullanım değerine bakarak tasarruf edilen suyu ekonomik olarak değerlendirmektedir. Doğal hayat su ihtiyacının pazar ve pazar dışı faydaları bu araştırmanın parçası olarak değerlendirilmemiştir. Ancak, gölge değeri tasarruf edilen suyu alt havzalardaki diğer üretken kullanımlardan ayırmanın maliyetini temsil etmek için değerlendirilmiştir.

FD bölgesindeki ortalama pazar fiyatlarına göre, ana hat hidrogüç ve sulu tarım değerleri sırasıyla yılda 3,5 milyar ABD Doları ve 4,8 milyar ABD Doları'dır. Hidroekonomik model kullanılarak simülasyonlar gerçekleştirilmiş ve tüm alt havzalarda tasarruf edilen suyun sulu tarım SKV iyileştirmelerinde yüzde 30'dan kaynaklandığını göstermekte, senaryolara dayanarak marjinal faydaların değeri 200 milyon ABD Doları ila 1,45 milyar ABD Doları arasında değişmektedir. Sulu tarım en yüksek değerleri gösterdiği için tasarruf edilen suyla modelin ayarlanmasına rağmen değerler ek hidrogüç ve sulu tarım arasında dağıtılabilir. Model hidrogüç barajlarının genişlemesini dikkate almamaktadır – yalnızca mevcut tesislerde tasarruf edilen suyun kullanımını dikkate almaktadır. Çevresel çıkışlar için farklı hacimlerde tasarruf edilen su için gölge değerler, senaryolara bağlı olarak 286 milyon ABD Doları ila 515 milyon ABD Doları arasında değişebilmektedir. Tüm değerler ortalama pazar fiyatlarına dayanmakta ve çarpan etkilerini hesaba katmamaktadır. Sulu tarımda SKV iyileştirmelerinden elde edilen tasarruf edilmiş su, doğal hayati desteklemek için kullanılmalıdır, sulu tarımla karşılaştırıldığında nispeten düşük bir gölge değeri vardır.

Araştırma, halen FD havzasının komşu bölgedeki ekonomilere önemli derecede olumsuz etkileri bulunan su kalitesinin bozulması ve sis ve toz fırtınaları gibi sistem dışındaki harici etkilere neden olan büyük baskı altında olduğunu doğrulamaktadır. Havza, ağırlıklı olarak su kaynakları bakış açısı ile yönetilmekte ve su yönetimi açısından yeniden değerlendirilmelidir. Tasarruf edilen suyun potansiyel üretken kullanımları kayda değerdir ve hidrogüç, sulu tarım, tuzluluk yönetimi, sulak alanlar ve deniz kıyısı ekosistemi ürün ve hizmetleri dahil üretim kullanımı çeşitleri için alt havzalarda birleştirici şekilde yönetilmektedir.

Araştırma sulu tarım SKV'nin iyileştirilmesi, alt havzalarda tarımsal verimi arttırmak için tasarruf edilen suyun kullanılması ve/veya hidrogüç üretiminin arttırılması (suyun tüketilmeden kullanılması) ve suyun çevresel akıntılara ve ekosistem ürünleri ve hizmetlerinin iyileştirilmesine (suyun tüketilerek kullanılması) ayrılması için önemli bir fırsat olduğunu ortaya koymuştur. Bununla birlikte, bir uyarı bulunmaktadır: Her alt havzada çiftlik seviyesinde, urun deseni seçimi, sulama kanalları, drenaj sistemleri hakkında yeterli bilgi bulunmamaktadır. Tasarruf edilen suyla alt havzalarda doğru yönetim seçeneklerini tanımlamak için ayrıntılı bir çalışmaya ihtiyaç duyulmaktadır. FD bölgesi doğal olarak tuzluluk sorunlarına yatkındır dolayısıyla ekosistemi ve tarımsal verimi etkilemektedir. Tuzluluğu azaltmak için gerekli önlemler alınmazsa, mevcut verimlilik seviyelerinde tarımsal faaliyette daha fazla genişlemenin desteklenmesi sorunu şiddetli hale getirecektir.

Kurumsal çalışmalar, eğitim ve kısa, orta ve uzun vadeli yatırımlar ile geleceğe yönelik işbirliğine dayalı çalışmalar yürütülebilir.

The four riparian countries in the Euphrates and Tigris (ET) Region (Iran, Iraq, Syria and Turkey) recognise that rapid population growth and economic development will increase the demands for water for energy production, food production, industry and domestic use at the regional level while ecosystem goods and services need to be maintained and/or restored. Hence the pressure on the freshwater resources in the region will increase unless radical measures to generate more value from the existing water resources for all the riparian countries are implemented. Water use development in one part of a transboundary river system may impact riparians in other parts through changes in water flow (volume), water quality and/or impacts beyond the basin through dust flows at neighbouring regions or other externalities at the coastal zone. The management of transboundary water resources such as those found in the ET Region therefore connect riparian countries and is considered a regional public good.

Some form of common approach to the management of the transboundary resource is necessary to secure future benefits from the water resources in the region, at the least in the face of emerging challenges of climate change that may lead to drier climate. From a foreign policy perspective the riparian countries acknowledge a common agenda of peace, stability and economic development, in which transboundary water resources management and development, trade and cooperation are important features because of the high value of goods and services that can be generated. Market benefits generated in different parts of the basin such as electricity can subsequently be traded in a market. Other benefits such as flood protection, wetland preservation and restoration and management of dust will benefit a larger region and can thus if provided promote regional integration and cooperation in several areas. Such an approach can bring stability and providing more opportunities to the four economies that currently are relatively isolated from each other.

In this study our hypothesis is that there are options to generate more benefits from a common approach to water resources management and development in the ET region and that the water resources currently are sub-optimally managed from the regional perspective. To test the hypothesis the study models the current economic value from the generation of hydropower, irrigated agriculture and ecosystem services and simulates the generation of benefits from cooperative action when viewed from a regional perspective.

For the purpose of the modelling and analysis our initial approach is to treat the ET region as one unit (i.e. one borderless region) and model scenarios in water use, water use efficiency improvements, and saved water, at this unit of analysis. In this regard the study aims to provide a starting point where stakeholders will have access to the same macro level information and building understanding and confidence in asking questions and seeking cooperative solutions on regional development challenges. For transparency, the model is populated with remote sensing data and other publicly available data, which in subsequent work can be augmented by the riparian countries, including adding more detailed ground proofed data by each riparian. Expert opinion has been relied on to a large degree to interpret the hydrological flows in the highly regulated ET region and full agreement on the hydrology has not been achieved at this stage.

Options to increase Water Use Efficiency (WUE) and generate more value in the region from water management and development will demand a good understanding of the political economy of the region. Therefore, a reference/observer group with participants from the four countries and three regional institutions has provided input to all stages of the study and in particular helped to identify a set of cooperative options that can be explored in subsequent collaborative work.

The target audience for this study and direct beneficiaries of the study are policy makers in the ET region. The aim is to promote partnerships, networks and ownership amongst ET riparian officials and other regional actors for subsequent cooperative analysis. In Box 1 the specific study objectives are outlined.

Box 1 Specific Study Objectives

1. To develop and provide an analytical and evidence based macro level approach for assessing benefits from management and development of the water resources in the Euphrates and Tigris system using a 'One Basin Approach', focusing on an assessment of system–wide benefits through management of irrigation, hydropower and environmental flows.

2. To prepare a baseline description of the Euphrates and Tigris system including a physical description (hydropower production facilities; irrigated agriculture; salinity; and wetlands/marshlands) using remote sensing technologies and publicly available data.

3. To develop a hydroeconomic model linking economics to hydrological flows, providing evidence to facilitate system-wide management options analysis and illustrating trade-offs between water use options in monetary terms.

4. To provide a basis for exploring cooperative system wide management and development options promoting regional investment opportunities in water informatics, governance and services (multilateral and national scales).

2.1 Why SIWI and partners?

The study was conceived from the discussions at a World Water Week (WWW) 2010 Seminar: Charting Cooperative Paths on the Water and Development Nexus in the Euphrates-Tigris Rivers System. During the seminar the participants asked for a neutral analysis based on quantitative data on the potential for benefit generation and sharing in water management and development in the ET region. From this initial suggestion, the current study was designed.

A reference/observer group was established for the project consisting of two government representatives from Iran, Iraq, Syria, and Turkey and representatives from regional institutions (American University of Beirut, the International Centre for Biosaline Agriculture, and the International Center for Agricultural Research in the Dry Areas). Four independent international advisors on hydrology, agriculture and economics have provided advice throughout the study.

The individual composition of the reference/observer group has changed over the course of the project and more interested partners have joined.

The study is financed by the Swedish International Development Cooperation Agency (Sida) within the framework of "The Swedish Strategy for Development Cooperation with Middle East and North Africa" that focuses on democratic development and human rights; sustainable management and development of transboundary water resources; and regional economic integration.[1] Sida is also financing a training program for all the Euphrates and Tigris system riparians on regional integration for which this study will provide more in-depth information on water and regional development.

SIWI takes full responsibility for the findings and the presentation of the study. The SIWI project team is responsible for the choice and the presentation of the facts contained in this study and for the opinions expressed therein, which are not necessarily those of Sida, the study financier, the reference/observer group members, or the independent advisors.

Photo: Jakob Granit, SIWI

[1] http://sidapublications.citat.se/interface/stream/mabstream.asp?filetype=1&orderlistmainid=2852&printfileid=2852&filex=3639112177524 (last accessed 2011-07-01)

The methodology comprised four mains steps:

Step 1: Establish a Euphrates and Tigris region baseline
The initial step of the study collected land use and hydrological data. To manage the hydrological and land use data, a Geographic Information System (GIS) was used as the placeholder for the data allowing for multiple analysis of geo-referenced data. Remote sensing data was used where possible, allowing for replicability and validation of data across the large and data scarce study region. Remote sensing data was combined with international available data sources (from international organisations such as the United Nations). This data sourcing approach enabled a common approach to the presentation of data across the region. This approach has limitations as the data may be outdated and it did not allow for the inclusion of more detailed country level input data. From this information a rudimentary lumped conceptual hydrological model based on the water balance in 13 sub-basins was developed. In the absence of available ground proofed hydrologic data expert opinion was used for the hydrological model calibration and validation.

Step 2: Establish baseline economic values for irrigated agriculture and hydropower
The irrigated land areas, irrigated agriculture water use and average prices for irrigated agriculture were estimated for each of the 13 sub-basins. Similarly, baseline values of hydropower generated in existing facilities and facilities under construction were estimated in the sub-basins in the Euphrates and Tigris region. Finally, a preliminary qualitative characterisation was carried out for wetlands, salinity and the coastal ecosystem goods and services using literature references. These baseline economic values can then be compared to marginal benefits obtained from the use of saved water.

Step 3: Construct a hydroeconomic model for analysing marginal benefits from Water Use Efficiency improvements
The hydroeconomic model builds the relationship between the use, economic value and hydrological parameters in the sub-basins. The hydroeconomic simulation model allows for simulation of management alternatives, including an estimate of the monetary value of alternative management options based on Water Use Efficiency (WUE) improvements and the allocation of saved water in the main regulated river stems to additional productive uses.

The principle approach to achieve additional water for benefit generation in the Euphrates and Tigris region is to increase the WUE in irrigated agriculture, which could include agricultural water delivery, application and management techniques. This will allow for a corresponding reduction in the abstraction of surface water from the main river stems.

Step 4: Engagement with the reference/observer group
Throughout the study, the project team interacted with the reference/observer group in three formal meetings and through e-mail exchange to guide the implementation of the study and to identify a set of cooperative options that can be explored in subsequent collaborative work.

On March 1-2, 2011, a first reference/observer group meeting was held in Stockholm where the participants presented their views on the approach and direction of the study. A second reference/observer group meeting was organised on August 23, 2011 to discuss the first draft of the study report in connection with a seminar organised at the World Water Week on Hydroeconomic Modelling[2] in Stockholm, Sweden. The second draft of the report was discussed in a reference/observer group meeting in Teheran, Iran on October 1 and in Istanbul, Turkey on October 5, 2011.

In the next section details of the study methodology and results of the baseline characterisation are presented.

[2] www.worldwaterweek.org/sa/node.asp?node=1079&selEvent=&filter=1&mySchedule=&txbFreeText=&selTheme=&selYear=2011%2D08%2D22&selRegion=&sa_content_url=%2Fplugins%2FEventFinder%2Fevent%2Easp&sa_title=Hydroeconomic+Modelling+in+Basins%3A+Practice%2C+Challenges+and+Rewards&id=4&event=365 (last accessed 2011-09-24)

4. Euphrates and Tigris Baseline Characterisation

The baseline characterisation involved a number of activities:

1. delineation of 13 sub-basins in the Euphrates and Tigris system;
2. estimation of baseline hydrological flows for 13 sub-basins as background data;
3. estimation of the irrigated areas in the sub-basins; the irrigated area water use and an estimate of the value of irrigated agriculture;
4. estimation of hydropower production facilities (including plants well advanced under construction) in the sub-basins and and average commercial value of hydropower production;
5. qualitative characterisation of the status of wetlands and the extent of salinity;
6. characterisation of the minimum flow requirement at the sea coast.

Due to the variation in data sources (remote sensing and international databases), the baselines represent a range of dates and not a single point in time. For the purpose of this study, the scale of the analysis used is the Euphrates and Tigris river system with its sub-basins at the confluence of the Euphrates and the Tigris rivers at Al Qurnah and to the terminus at the Coastal Sea via the Shatt-al-Arab. The Karun river basin that is artificially connected to the Shatt-al-Arab (main stem of the ET basin about 70 km northwest of the sea coast) is not included in the analysis. From this 'one basin,' macro-scale approach, 13 sub-basins were delineated for the purpose of the analysis. The drivers for this approach include:

1. the river basin with its sub-basins is the basic hydrological unit and has been long recognised as the appropriate scale for managing and planning water resource management;
2. the objective of the study was to think beyond the administrative or country boundaries, which are also beyond the basin;
3. a regional approach allows for analysis of a wider set of benefits and management options, and subsequent distribution through different forms such as market mechanisms, trade, or compensation.

For the purpose of illustration a whole area Landsat TM mosaic is presented in Figure 1.

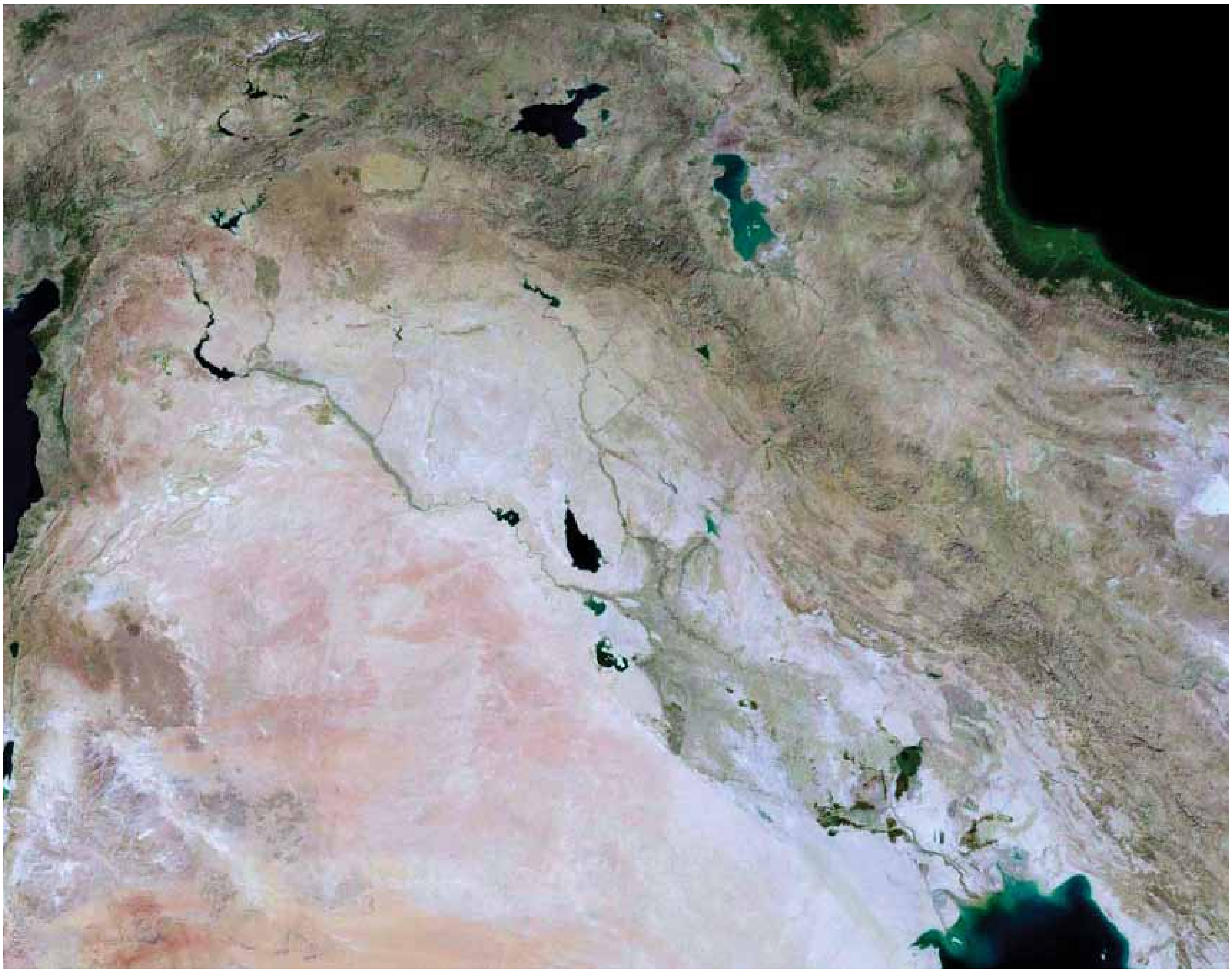

Figure 1. Euphrates and Tigris region Landsat TM mosaic.

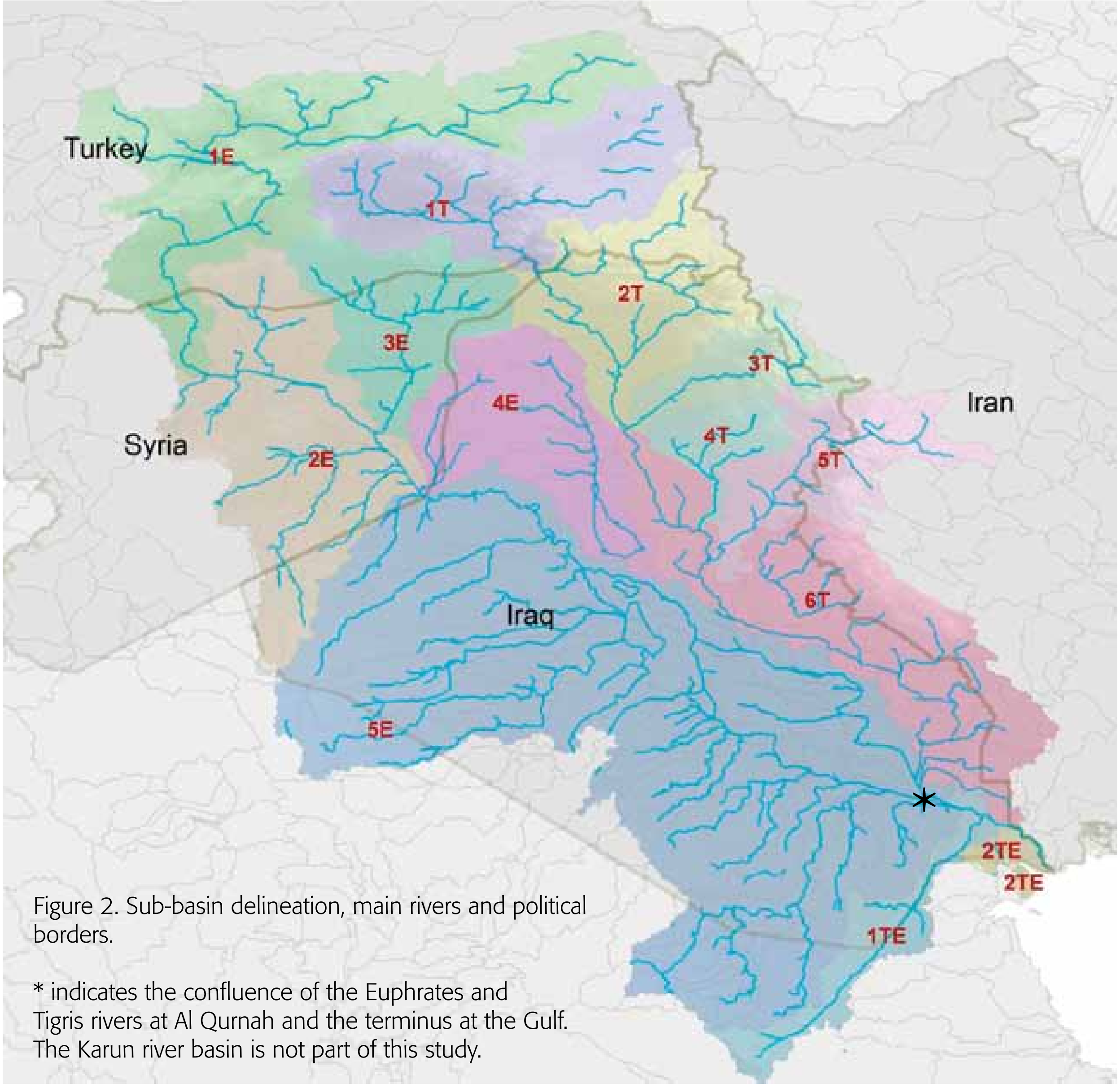

Figure 2. Sub-basin delineation, main rivers and political borders.

* indicates the confluence of the Euphrates and Tigris rivers at Al Qurnah and the terminus at the Gulf. The Karun river basin is not part of this study.

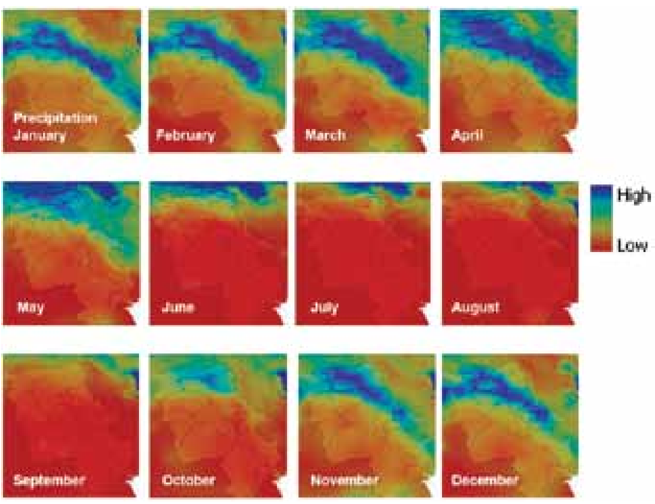

Figure 3. Monthly precipitation Euphrates-Tigris region.

4.1 Basin and sub-basin delineation

a) Delineation method

The delineation of the basin and sub-basin set the scale of the analysis and the boundaries of the Euphrates and Tigris system for the purposes of the study.

The basin and associated sub-basins were compiled using Shuttle Radar Topography Mission (SRTM) data. The SRTM data sources provide illustrations of elevation data, river lines, dam reservoirs and sub-basin delineation through quick terrain modelling packages and other Geographic Information System (GIS) analysis.[3] River patterns (first order streams), watersheds, a shaded relief model and a 3D model were obtained from this data source. Data on monthly precipitation was approximated using FAO Local Climate Estimator (LocClim) and Global Climate Data (WorldClim).

[3] SRTM is a high resolution digital elevation model of the Earth, with 9m grid density, a linear vertical absolute height error of less than 16m, linear vertical related height error of less than 10m.

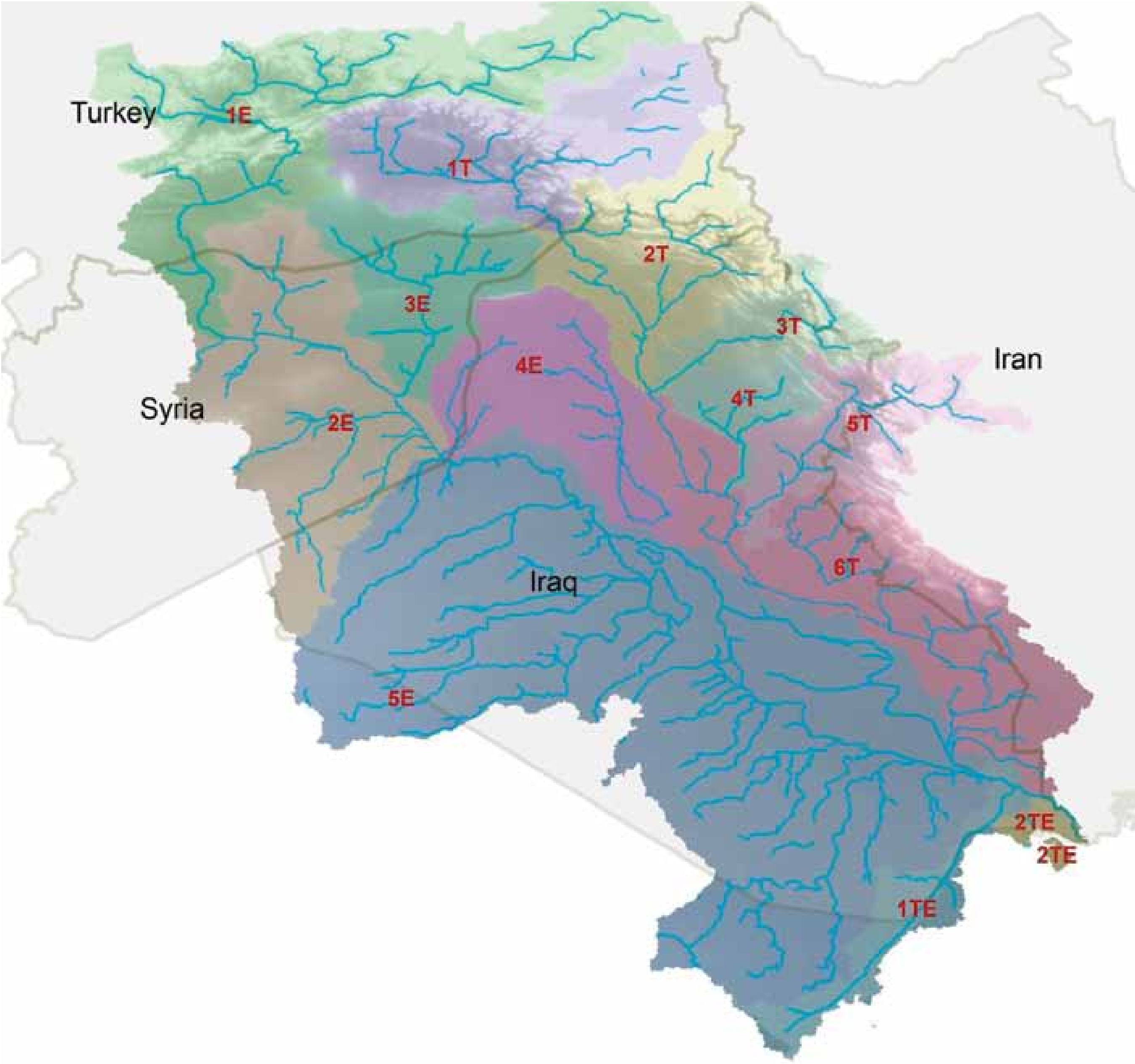

Figure 4. STRM main rivers and elevation data (white corresponds to highlands/mountains and grey to lowlands).

Political boundaries are retrieved from the Database of Global Administrative Areas (GADM) which is a spatial database of the location of the world's administrative areas for use in GIS. All geo-referenced data generated are stored in ArcGIS 9.3 format (a software package for GIS). For visualisation purposes a composite LANDSAT TM scene (satellite image) was used as a backdrop for different views in the GIS. The Landsat Program is a series of earth-observing satellite missions jointly managed by National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey.

b) Results – sub-basin delineation

The sub-basin areas are presented in Figure 2. Elevation data is visualised in Figure 4 against main rivers and sub-basins. Monthly precipitation in the Euphrates and Tigris region is illustrated in Figure 3. For the purpose of the analysis the Euphrates and Tigris basin was divided into 13 sub-basins: six in the Tigris (T), five in the Euphrates (E) and two joint basins (TE). The connectivity between the sub-basins is listed in Table 1.

c) Method – hydrological flows

The objective of the assessment of hydrological flows is to provide a baseline perspective of water resources and hydrology in the ET system. The hydrological flows are presented as background information and are not used in the hydroeconomic model. The estimated hydrological flows only provide an overall sense of the volumes of water that are available in the system as a whole. Only marginal values of change in flow are used in the hydroeconomic model based on WUE improvements.

The average annual discharge in the highly regulated ET river system is difficult to determine due to large yearly fluctuations. The World Bank (2006) for example uses a range of annual water

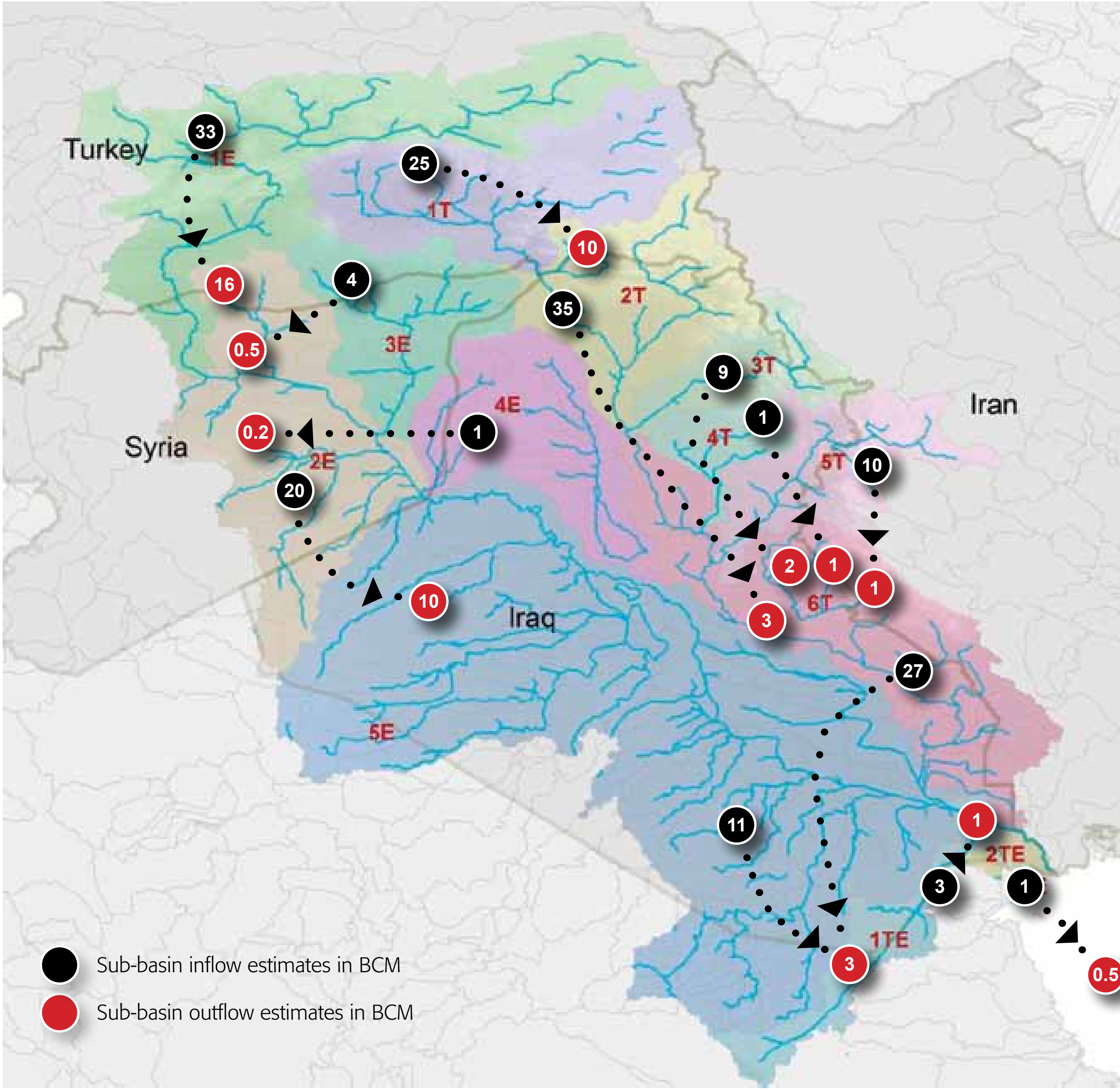

Figure 5 Sub-basin links and estimates of flows (baseline).

Table 1. Connectivity between sub-basins

Euphrates sub-basin connectivity	Tigris sub-basins connectivity
• 1E ► 2E • 3E ► 2E • 4E ► 2E • 2E ► 5E • 5E ► 1TE	• 1T ► 2T • 2T ► 6T • 3T ► 6T • 4T ► 6T • 5T ► 6T
The connectivity between the sub-basins at the terminus are as follows: • 6T ► 1TE • 1TE ► 2TE	
• 6T ► 4E, connected through the man-made Tharthar canal.	

Table 2. Water resources summary data per sub-basin

Basin ID	River Name from Aquastat	IN BCM	OUT BCM	Area km²
1E	Euphrates Turkey	33,1	15,7	8 883 130
2E	Euphrates Syria	20,2	10	7 768 970
3E	Nahr al Khabur Syria	4,3	0,5	3 680 970
4E	Tharthar Lake	1,3	0,2	4 544 630
5E	Euphrates Iraq	11,4	3	27 084 400
1T	Tigris Turkey	25,1	10	5 776 100
2T	Greater Zab and Khabur Iraq	35,4	16	4 641 130
3T	Lesser Zab	9,2	2	2 049 070
4T	Al-Adhaim	0,9	0,7	1 240 250
5T	Diyala	9,6	1	3 397 730
6T	Tigris Iraq	26,8	3	7 874 870
1TE	Hawr al Hammar	3,3	1	2 265 360
2TE	Shatt Al-Arab	1,1	0,1	444 629
Total E+T	**Euphrates and Tigris**	**–**	**–**	**79 651 239**

resources likely to be available to Iraq at between 59-75 billion cubic metres (BCM). The Karun River, originating in Iranian territory, has a mean annual flow of 25 BCM and flows into the Shatt Al-Arab, to which it brings a large amount of fresh water just before reaching the sea. In this baseline analysis we have not accounted for the flows from the Karun river to the terminus.

The data on precipitation, temperature and sub-surface water flows was obtained using FAO LocClim data as random points in the middle of each sub-basin and then geo-referenced.[4,5]

Residual rainfall is equal to monthly precipitation minus evapotranspiration. The runoff (RO) in each sub-basin was compiled using Aquastat water resources reports for each country. (FAO, 2011).

RO data points within the sub-basin were geo-referenced with weighted averages from available points nearest to or within the sub-basin using expert opinion. By combining LocClim data with RO data it was possible to calculate the input for each sub-basin. The same procedure was done for calculating the output from each sub-basin. The results for this baseline analysis are found in Table 2. The metrics are calculated using Excel.

d) Results – hydrological flows

Estimated summary results of the hydrological flows for the baseline characterisation process are presented in Table 2. It should be noted that the approach of calculating estimates for IN and OUT flows in sub-basins can be improved particularly if long term ground proofed data would be available. The existing bilateral water allocation agreement between Turkey and Syria (15.70 BCM per year) on the Euphrates river (1987 Protocol on matters pertaining to economic cooperation, Turkey and Syria) is entered as average yearly regulated RO value from sub-basin 1E to 2E.

4.2 Baseline economic values from irrigated agriculture

The purpose of the agriculture irrigation analysis is fourfold:

1. to estimate the irrigated land areas in the sub-basins;
2. to estimate irrigated agriculture water use in the sub-basins;
3. to estimate an average price for irrigated agriculture production per sub-basins;
4. to characterise efficiency of existing irrigation systems in the basin.

4.2.1 Baseline irrigated agriculture; area water use and market values in the sub-basins

a) Approach to estimate irrigated area water use

The irrigated land area was estimated based on data from the World Irrigation Map (from year 2000), updated with land classification based on data from Globecover (for year 2005), which is based on MODIS/MERIS data and geo-referenced in the GIS.[6]

The results of the analysis of irrigated land area are presented in Table 3 and visualised in Figure 7 (page 21).

An irrigation factor module was applied to estimate irrigated agriculture water use in the sub-basins. The irrigation factor module used is 1,000 litres/m^2/year for potential evapotranspiration less than 1,500 mm and 1,200 litres/m^2/year for potential evapotranspiration more than 1,500 mm (e.g. Beaumont, 1996). Irrigated agriculture water use was calculated for each sub-basin by multiplying the irrigated area by the irrigation factor.

[4] FAO Local Climate Estimator data as random points in the middle of each basin.

[5] WorldClim is a set of global climate grids with a spatial resolution of 1 km^2. It is commonly used for mapping and spatial modeling in a GIS or other computer programs. The data layers used in WorldClim are generated through interpolation of mean monthly climate data from weather stations on a 30 arc-second resolution grid (often referred to as "1 km^2" resolution) spanning 30 years of data. Variables included are monthly total precipitation, and monthly mean, minimum and maximum temperature, and 19 derived bioclimatic variables (Hijmans et al 2005). Daily data is not available on WorldClim or satellite imagery. Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. International Journal of Climatology 25: 1965-1978. The WorldClim database is under continuous development. The current version is Version 1.4 (release 3). www.worldclim.org.

Table 3. Sub-basin irrigated areas from World Irrigation Map (2000) updated with Globecover (2005)

Euphrates sub-basins (Ha)		**Tigris sub-basins (Ha)**		**Euphrates & Tigris to study terminus (Ha)**	
1E	424,152	1T	286,758	1TE	16,947
2E	310,680	2T	126,684	2TE	6,714
3E	460,044	3T	120,816	–	–
4E	30,852	4T	121,869	–	–
5E	1,825,659	5T	304,461	–	–
–	–	6T	1,298,826	–	–
Total	**3,051,387**	**–**	**2,259,414**	**–**	**23,661**

b) Approach to estimate irrigated agriculture value per hectare

To determine the irrigated agriculture value per hectare in the sub-basins we employed a four category indicator crop system:

- Annuals with low water use: indicator crop – wheat.
- Annuals with high water use: indicator crop – rice.
- Perennials with low water use: indicator crop – olives.
- Perennials with high water use: indicator crop – apples. and oranges.

The indicative values per hectare are presented in Table 4. The area of the four category indicator crops grown in each sub-basin and the value of agriculture in each sub-basin per category is presented in Table 5. To estimate the value of the crops grown in each sub-basin a combination of price data is used based on the FAO (for olives and rice), International Grains Council (for wheat), International Olive Council (for olive oil), USAID (for rice) sources and Eurostat (for apples and oranges). Using the four crop category defined above and based on FAO data, an estimation of the major crops grown in each sub-basins was performed.

c) Results – baseline economic values for irrigated agriculture

The average value (revenue) of a hectare per sub-basin is presented in Table 6. These estimates are used directly in the hydroeconomic model.[7] The estimated overall baseline value of irrigated agriculture in the ET basin is **4.8 billion USD** per annum (Table 6).

d) Irrigation agriculture water use efficiency in the Euphrates and Tigris

Information in international literature sources indicates that the area of improved irrigation systems is low across all sub basins. In Iraq, FAO data indicates that as little as 8,000 hectares or less than 0.5 percent of the irrigated land has more advanced systems than surface irrigation. For Turkey, the area of sprinkler irrigation is quoted as 6 percent and 2 percent for drip irrigation. In Iran, it is 3 percent and 5 percent respectively, and in Syria is slightly higher at 10 percent for sprinkler irrigation and 5 percent for drip. Plusquellec (2006) suggests that there is 8.5 percent for both sprinkler and drip irrigation in Syria, but that this is more used in areas abstracting groundwater rather than surface water sources.

The status is also supported by the World Bank (2005) who estimates that installed capacity for advanced irrigation systems is below 10 percent in most developing regions. The use of more advanced systems tends to be restricted to higher value crops (fruit and vegetables), with very little in field crops. From these sources, we can estimate that less than 5 percent of the irrigated area in the basin is serviced by systems other than surface irrigation (flood and furrow). Therefore the capacity for water use efficiency improvements in irrigated agriculture is significant.

Successful implementation of irrigated agriculture WUE improvements requires a developed industry, skilled engineers, technicians and farmers, and effective maintenance. They are most successful in areas where water is scarce and expensive, so that farmers can recover the system cost by reducing irrigation losses and increasing productivity. When water is ample and low in cost, farmers have little incentive to convert to modern systems.

Modern irrigation systems such as sprinkler and drip irrigation can be efficient only if they are managed properly. The efficiency of modern systems can be as low as that of surface systems if poorly managed. Modern systems do not guarantee high efficiency; surface systems may be better under certain circumstances especially as farmers know them well. Modern systems increase productivity not because it reduces system losses, rather due to better control, higher irrigation uniformity and frequency, better fertilization and other factors.

The lower efficiency of surface systems is due to higher deep percolation and runoff losses. These losses occur at the field level but may be fully or partially recovered at the scheme or basin levels by recycling drainage and runoff losses or by pumping deep percolation losses from groundwater aquifers. Of course these are important losses to the farmer and recovering this water has a cost – but these are not total losses at the larger scale. As Table 7 shows, much improvement can be made by improved management of existing systems.

[6] www.gofc-gold.uni-jena.de/The Globecover project produced a global land-cover map for the year 2005, using as its main source of data the fine resolution (300 meters) mode data from MERIS sensor on-board ENVISAT satellite.

[7] Gross or net margins (i.e. account for production costs) could form additional analysis.

Table 4. Indicative Value per Hectare

Crop Category	Indicative Crop	Value (USD)/tonne	Yield/Ha	Value (USD)/Ha
Annual – low water use	Rice	400	2 tonnes	800
Annual – high water use	Wheat	250	1.5 tonnes	375
Perennial – high water use	Apples & Oranges	150	22 tonnes	3,300
Perennial – low water use	Olives	260	1.6 tonnes (Oil)	416

Table 5. Area and value of Agriculture in each sub-basin per crop category (Ha, USD$)

Annual Crops (High)			Annual Crops (Low)		Perennial Crops (High)		Perennial Crops (Low)	
Sub-basin	Area (Ha) '000	Crop Value (USD)	Area (Ha) '000	Crop Value (USD)	Area (Ha) '000	Crop Value (USD)	Area (Ha) '000	Crop Value (USD)
1E	127	101,6	212	79,5	85	280,5	0	0
2E	155	124	62	23,3	62	204,6	31	12,9
3E	230	184	92	34,5	92	303,6	46	19,1
4E	18	14,4	0	0	7,5	24,8	4,5	1,9
5E	365	292	1186	444,8	182,5	602,3	91	37,9
1T	86	68,8	143,0	53,6	57	188,1	0	0
2T	75,5	60,4	0	0	31,5	104	19	7,9
3T	72	57,6	0	0	30	99	18	7,5
4T	72	57,6	0	0	30	99	18	7,5
5T	61	48,8	198	74,3	30	99	15	6,2
6T	260	208	843	316,1	130	429	65	27
1TE	4	3,2	12	4,5	0	0	0	0
2TE	1,5	1,2	4,5	1,7	0	0	0	0
	1 527	**1,221,6**	**2 752,5**	**1,032,2**	**737,5**	**2,433,8**	**307,5**	**100,9**

Table 6. Average value of hectare (ha) per sub-basin

Sub-Basin	Hectare Area (ha)	Total Value (USD)	USD/ha
1E	424 000	461 600 000	1 089
2E	310 000	364 800 000	1 177
3E	460 000	541 200 000	1 177
4E	30 000	41 100 000	1 370
5E	1 824 500	1 377 000 000	755
1T	286 000	310 500 000	1 086
2T	126 000	172 300 000	1 367
3T	120 000	164 100 000	1 368
4T	120 000	164 100 000	1 368
5T	304 000	228 300 000	751
6T	1 298 000	980 100 000	755
1TE	16 000	12 000 000	750
2TE	6 000	4 500 000	750
Total	**5 324 500**	**4 821 600 000**	**906**

Table 7. Water Use Efficiency Estimates

Mechanism for Water Saving	Estimated Improved WUE (%)
Improved Management – Current Crops	15 to 20%
Improved Irrigation System	
• Flood to Improved Furrow	10 to 20%
• Surface to Sprinkler	20%
• Surface to Drip	30%
Crop Changes	20%
On-Farm Infrastructure (Delivery)	20%
Local/Regional Delivery Systems	30%

4.2.2 Hydropower baseline; market values

a) Method – hydropower

There are a large number of hydropower production facilities in the sub-basins, with a wide range of dam structural heights. The large hydropower dams are in the upstream part of the system. Most of these dams are for single purpose use (generation of electricity) but the water storage is also used in some cases for withdrawal for irrigation purposes. Monthly flows at Hit in Iraq on the Euphrates river before and after the construction of the upstream storage illustrate the increase in storage capacity (Figure 6). The good regulation capacity upstream indicates that water saved through improved WUE in irrigated agriculture will not be discharged as spillages from the reservoirs. The saved water will be stored and can be discharged through the hydropower plants at times when it is needed for irrigation purposes downstream.

The hydropower dams are primarily located in the upstream part of the ET region (see Figure 7). Several public sources have been used to identify the hydropower storage structures. Not all planned hydropower facilities were included only those that could be verified by the reference/observer group. The dams are predominately larger scale dams.[8] GRID UNEP (2001) provided information on facility locations, validated by Landsat TM. To simplify the modelling process, only the main hydropower production facilities were modelled, those with height of 11 meters or higher (up to 160 m). Only existing production facilities were modelled including three sites that are at an advanced stage of construction and one site that is soon under construction (see Table 8). Many reservoirs are of multipurpose use character including for hydropower, water for irrigation and flood control. In this study we have not modelled the multipurpose storage capacity but treated the dams as single purpose hydropower generation facilities in order to estimate the values of hydropower production. The analysis does not also consider negative impacts from large scale storage including environment or social issues related to large scale dam program development.

An indicative commercial value of 8 cents per kWh generated was used to calculate the commercial value of hydropower generation with a total plant efficiency of 90 percent. The hydroelectricity value represents an average world market price at the end of 2010. This figure does not account for the multiplier effects of energy use in the economy.

The study assumes excess height at all sites and capacity to generate hydropower because of the additional storage capacity. A standard equation to calculate theoretical additional available power was used for each hydropower site under different water saving scenarios:

E(Wh) = plant efficiency (90 percent) *density (kg/m^3) *head (m) * additional water flow (as estimated from saved flow) (m^3/s) *gravity (9,81 m/s^2) *hours per year of operation (8760)

b) Results – baseline market hydropower generation values

The summary details of the hydropower production facilities are presented in Table 8.

Total annual energy production in the Euphrates sub-basins, exclusive Baath HPP is 33.9 TWh. The total annual energy production in Tigris including Llisu and Cizre, which are under construction, and excluding Silvan, is 11.2 TWh. This translates to an estimated baseline value of hydropower generated in existing and facilities under construction at **3.5 billion USD** per annum, using average market prices.

[8] The International Commission for Large Dams (ICOLD/CIGB) leads a listing of the large dams of the whole world. They must fulfil the ICOLD criteria, in order to be listed. A dam is a "large dam", if: Height > 15 m or Height > 10 m and [crown length > 500 m or memory space > 1 million m or calculation floods > 2000 m /s]

Table 8. Main hydropower production facilities and their capacity

Euphrates Hydropower	Head (m)	Capacity (MW)	Tigris Hydropower	Head (m)	Capacity (MW)
Keban	70	1 330	Kralkizi	68	94
Karakaya	160	1 800	Dicle	65	110
Ataturk	140	2 400	Kayser	130	90
Birecik	44	672	Silvan*	155	150
Karkamis	25	189	Batman**	60	198
Tichrin	40	630	Garzan	100	90
Tabqa	60	824	Llisu**	110	1 200
Baath	14	75	Cizre**	35	240
Haditha	70	660	Mosul 1	73.5	750
			Mosul 2	11	60
			Sammarra	12	80
			Dokan	96	400
			Derbendekan	70	166
			Hamrin	45	50
Total		**8 580**			**3 678**

*Soon under construction
** Under construction

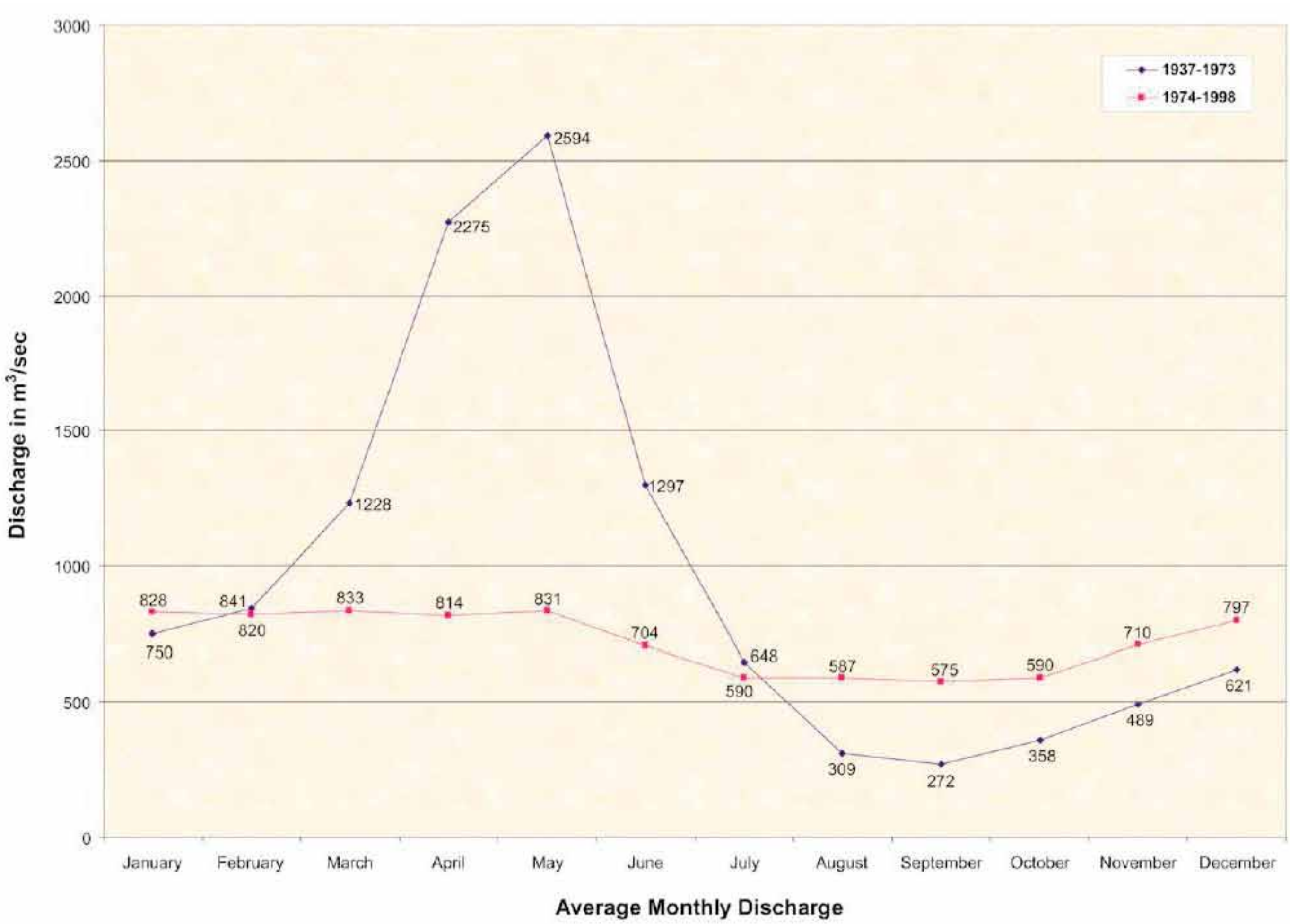

Figure 6. Flows at Hit flow gauging station illustrating how the system is regulated (UNEP, 2001).

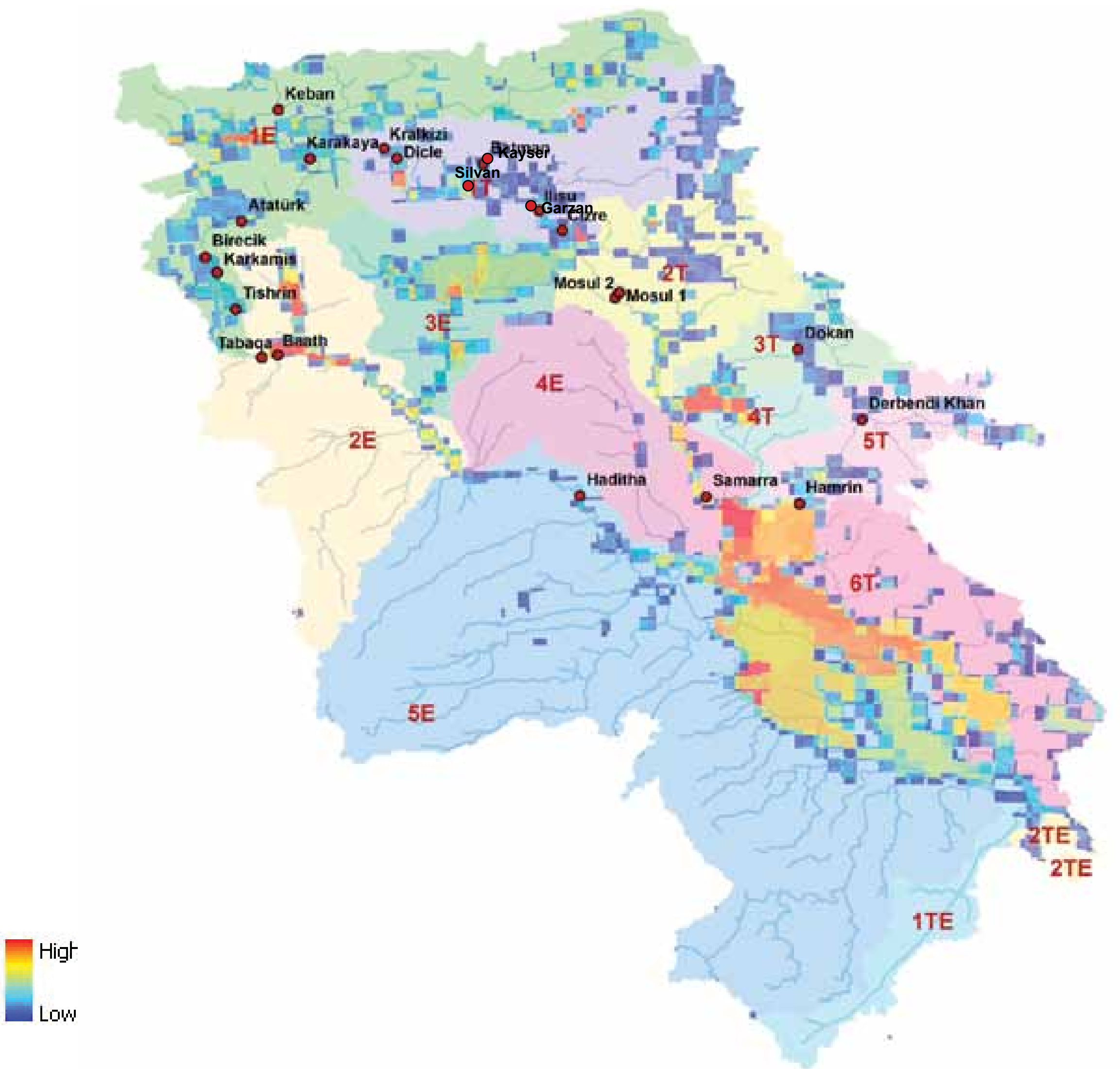

Figure 7. Sub-basins, country boundaries and locations of existing dams and some of the dams under construction and irrigated agricultural areas (red depicts areas of high irrigated agriculture and blue low irrigated agriculture).

4.2.3 Ecosystems; wetlands, salinity and sea coast

In this section a qualitative analysis of the status of wetlands, salinity and the sea coast is presented. This is presented as baseline information and was not directly used in the hydroeconomic model. The information is used as an input to the different scenarios performed in the modelling work.

a) Wetlands

The core of the regions wetlands are the Southern Iraqi marshes, centred in the area around the confluence of the ET and typically divided into three major areas, namely, the Hawr Al Hammar, Central and Al Hawizeh Marshes. The Southern Iraqi marshlands alone once covered over 20,000 km^2, a mosaic of diverse habitats and environmental conditions. Historically the wetland systems constituted a chain of interconnected marsh and lake complexes within the flat alluvial plain. With high variability of flow in the main rivers and high evaporation, marsh areas reduced by as much as 30 percent to 50 percent during the summer. Other significant natural wetlands in Iraq include Shari Lake; Haur Al Shuaicha; Al-Dalmaj Marsh; Seilaibat Marsh and Sawa Lake. Over 30-40 years, over 90 percent of Southern Iraqi marshlands desiccated. 1973 marshland area of 8,926 km^2 (extending to 20,000 km^2 during seasonal inundation) was reduced to 1,297 km^2. Less than 10 percent of the Southern Iraqi area remained as a functioning marshland by the year 2000. Central and Hawr Al-Hammar were virtually destroyed by 2000, with respectively 97 percent and 94 percent of land cover transformed to bare land/salt crusts. The only remaining marsh of any size was the northern portion of Al-Hawizeh. Endemic mammals and fish are now extinct. Coastal fisheries in the northern Persian Sea has experienced a sharp decline. In attempting to manage wetland restoration in the ET region, particularly in the downstream sub-basins where the majority of significant marshes are located, appropriate policies and practices should focus on improving water quantity. While the presence of adequate water quantity is critical for wetland restoration, successful restoration also requires additional dimensions:

- proper water hydro-period (i.e. the period of time water is at or near the surface),
- proper hydro-pattern (i.e. the spatial distribution of water over the area),
- adequate flow through the marshes (i.e. the water must not stagnate), and
- adequate water quality status (although this is partially a function of water quantity).

b) Salinity

The Euphrates and Tigris region is naturally vulnerable to salinity, due to combinations of naturally calcareous geology in upstream reaches (generating highly saline alluvial silt), highly permeable sediments in middle and lower reaches (amenable to groundwater recharge), low rainfall and high evaporation – around 2,500 mm (especially in the summer months). By the 1970s, 24,000 ha in the Lower Euphrates Valley of Syria was abandoned due to high salinity levels (10,500 ha physically abandoned; 14,000 ha growing irregular crops to maintain ownership rights). The rate of abandonment is over 2,000 ha/year and is accelerating. 10,000 ha of privately developed irrigation in Syria were abandoned because of salinity, including villages. In Iraq, deteriorating water quantity and quality have put 40 percent of historically irrigated areas out of production. In the Lower Euphrates Valley of Syria during the 1970s, half of the cropped area producing reasonable yields was unaffected by salinity. About 40 percent experienced a moderate reduction in yield and 10 percent a severe reduction due to salinity. In Iraq, 70 percent of lands affected by high soil salinity were experiencing limited crop yields.

Salinity levels only reached 1,000 ppm in the Euphrates in the lowest reaches by the mid-1970s. Salinity has increased gradually over the last three decades, at a rate of approximately 100 ppm per year. At Ramadi, salinity levels reaching 250 to 500 mg of chlorides per litre render water unsuitable for irrigating some crops. Salinity of Euphrates entering Iraq has more than doubled compared to 1973. Euphrates water is below quality levels useful for domestic or irrigation purposes downstream of Al Samawa. Reliant on Euphrates water until mid-1970s, Al Nassiriah now depends on Al Gharraf River as the main source of municipal water. Dependence on irrigation, fertilisers and chemicals, combined with sandy and gypsiferous soils, caused massive leaching of chemicals into groundwater. High extraction rates have degraded groundwater quality by increasing salinity (e.g. in Syria).

The consequences of salinity are principally detrimental effects on plant growth and yields, impacting on agricultural production. Heavily salinized soils become unproductive and are commonly abandoned. The highest concentrations of saline water occur in the summer as irrigation return flows coincide with seasonal low river flows. To manage salinity in the Euphrates and Tigris region, appropriate policies and practices could focus on increased water quantity. While the presence of adequate water quantity is critical for salinity management, successful management also requires additional dimensions, which are complementary to the agricultural efficiency improvements implemented to save water:

- adequate drainage facilities (poor drainage facilities cause farmlands to waterlog), requiring investment in adequate field level drainage systems,
- appropriate irrigation application, as over irrigation and flooding of fields raises water tables, polluting soils with salinized water. This requires more efficient use of water, maximizing per drop of water used, and
- efficiency of irrigation water conveyance. Lack of investment in delivery systems and extension work are the cause of persistent leaking canals. This recharges local aquifers with salts and raise water tables inhibiting leaching. This requires modernisation of old drainage schemes to improve conveyance efficiency through canal lining and pipeline networks, supplemented with modern field irrigation systems for increased irrigation ef ficiency.

b) Sea coast

The consequences of low outflow at the terminus are detrimental to the sea coastal marine ecosystem goods and services. These services are produced conjunctively with the wetlands and water quantity. Flow rate of 160 m^3/s is viewed as a necessary flow rate to maintain gravity flow irrigation, surge capacity and basic riverine ecology. A flow rate of 292 m^3/s is suggested as a minimum at Shat al Arab, to preserve its natural ecosystem, to transport agricultural and industrial wastes and to prevent sea water intrusion. Salinization, chemical contamination, acidification, eutrophication and microbial contamination are some of the impacts as a result of the quality and quantity of discharge at the terminus and sea coast.

The following section presents examples of hotspots that have a regional dimension. They were proposed by the reference/observer group. It is not a complete list of hotspots, only an illustration of the type of regional public goods issues that could be managed through cooperative action.

5.1 Climate change

Present climate

The climate in the ET region is largely part of the Mediterranean climate system, influenced by the North Atlantic weather systems, characterised by dry hot summers and mild, wet winters. Towards the southern and south-western part of the basin the climate becomes drier, thereby gradually shifting to steppe and desert climates. Precipitation in the region varies between more than 1,000 mm per year in the wetter Taurus and Zagros Mountains in the north and north-east, and less than 100 mm per year in the dry plains of Mesopotamia in the south and southwest. The potential evapotranspiration is above 1,000 mm per year in most of the region except in the far north, which further contributes to the very dry climate, primarily towards the south. There are two major flood periods in the river basin. The first is from November to March and is mainly due to the winter rainfall. The second occur in April and May and results largely from snow melt. This flood period generates around 50 percent of the runoff in the basin. Similar to most arid and semi-arid areas, the region experiences large variations in inter- and intra-annual precipitation making planning for agriculture and other water-dependent socio-economic activities challenging.

Predicted climate change

Climate predictions based on the Intergovernmental Panel on Climate Change (IPCC) A1B greenhouse gas emission scenario indicates substantial changes in temperature and precipitation for the region. The A1B scenario assumes a world of very rapid economic growth, a global population that peaks in the mid-century and rapid introduction of new and more efficient technologies. This scenario assumes that energy production is balanced across different sources (fossil intensive and non-fossil energy resources). Annual temperatures are projected to increase with 3,5°C over a period of 100 years (1980-1999 versus 2090-2099).
Similarly, precipitation changes according to IPCC are projected to decrease annually in the range of 5-30 percent, mainly during the winter season, with minor changes during the summer period.

Parallel with a total reduction of annual precipitation, the number of high intense rainfall events is predicted to increase (IPCC, 2007). Thus, it is likely that rainfall events will occur more seldom but be more intense, and thereby more destructive when they occur. This also implies an increase in severity and length of dry spells in between the rainfall events. A reduction of precipitation during the winter in combination with increased temperature also means that precipitation in the form of snow will decrease. This is particularly valid for the mountainous northern and north-eastern parts of the region. Furthermore, snow will gradually melt earlier in the spring season resulting in more early spring peak discharge. Reduced snow cover will also deprive the basin of a very important water storage media from the wetter winter to the dry summer season.

Impact of climate change on water resources

The combined effect of increased temperature, leading to increased evapotranspiration, and reduced precipitation will result in large scale relative changes in annual runoff (water availability). For the period 2090-2099 relative to 1980-1999, the decrease in runoff is predicted to be in the range of 5-40 percent for a majority of the basin. Discharge of the Euphrates River is projected to decrease between 29-73 percent by the end of the 21st century. For the Euphrates River, it has been estimated that 88 percent of the water in the river derives from precipitation falling in Turkey, i.e. mainly in sub-basin 1E, which means that downstream water availability is very sensitive to changes in the precipitation in this sub-basin, as well as the management of the water resources in this basin. In the Tigris River, it is estimated that about 60 percent of the water in the river is received through precipitation in the sub-basins downstream from Bagdad, i.e. to a large extent in sub-basins 5T and 6T. However, looking at the above figures, it is important to bear in mind that in a dry area even a very small change in precipitation will imply very large figures expressed in percentages. This is also a reason for the large uncertainties in the figures provided.

Adaptation to climate change

In order to adapt to reduced water availability a range of measures will be required, including increased water use efficiency and improved management of existing storage capacity (natural and artificial). It is fundamental to address water use in agricultural production as the largest water consumer. It is also of increasing importance to look into the allocation between different sectors, where it should be ensured that water is allocated to those sectors that provide socio-economic benefits for a basin or region as a whole.

5.2 Interbasin water transfer from adjacent (neighboring) basins

The minimum rainfall level to preserve environmental flows of Lake Urmia in Iran is 1,274 mm. In the past 15 years, rainfall has decreased in this basin (from an average rainfall decrease from 381 mm to 305 mm, and in highland areas of this basin, rainfall decreased from 601 mm to 416 mm). With this decrease in water level, salinization has caused regional problems, for agricultural production and health. To manage this issue, Iran is investigating an interbasin transfer from adjacent neighbouring basins of about 1,300 million cubic metres (MCM) of water.

5.3 Regional interdependence – dust and small particles

It has been observed that dust and small particles generated from dry plains and dry wetlands are being transported through the atmosphere by wind (vertical air and horisontal air movements). Poor water resources management is indirectly one of the most important root causes of the haze problem. Surface water diversion, dam construction, and overuse of water resources are activities that cause dryness of lands (including wetlands) in the basins. Soil type and grain size, soil moisture and land cover are determinants of levels of dust and small particles generated. The transportation of the pollutants in the environmental media is a source of substantial interdependence among Iraq, Iran and Pakistan. Recent investigations show that the source of dust and small particles in the sub-basins 5T and 6T are situated in Iraq. From here the dust and small particles are transported out of the sub-basins towards Iran and Pakistan. A recommended maximum value for concentration of dust in the context of human health is 150 $\mu gr/m^3$. Observed dust concentrations in many of western provinces in Iran have reached more than 3,000 $\mu gr/m^3$. Wetlands degradation in Iraq in the Central Hour, Hour-al Hammar, and partially Hour-al-Hoveize is a determinant of dust and small particles. As discussed in section 4.2.3, wetlands degradation is linked to water quantity and water resource management in particular in the downstream sub-basins.

5.4 Within basin transfers – example Thartar Lake

The first Thartar canal was excavated in 1953 to protect Baghdad from flooding by diverting Tigris River water to the Tharthar Lake. The second canal was built in 1985, in order to divert Tigris River waters to the Euphrates River to overcome water shortage in the Euphrates river. Major water losses to groundwater through the Tharthar canals, and Tharthar Lake has occurred since the canals were constructed. The canals are in highly permeable soils. Diverting the water to the Thartar depression has resulted in raising the water levels to about 60 meters above its original level. Groundwater has risen in the direction of flow south of Tharthar Lake and through capillary action has resulted in soil salinization. The Tharthar constructions eliminated flooding which in the past contributed to the leaching of accumulated salts and reduced the flow of fertile sediments to the flooded soils. The drainage system has caused the increase of groundwater mineralisation due to very high evaporation rates, and at the same time the drainage canals acts as a source for pollution of ground water due human and wind-blown waste that add up inside the drainage systems.

Detailed investigations need to be undertaken to understand the Thartar Lake system to explore if it is possible to make water savings to reduce salinity and utilise water to support wetland restoration or additional irrigated agriculture. There is also a possibility to save operation and maintenance costs if the drainage system can be re-assessed in light of new storage capacity upstream.

6.1 Purpose of the hydroeconomic simulation model

The hydroeconomic simulation model was developed to model potential marginal benefits in monetary terms from using saved water gained through irrigated agriculture WUE improvements. It established the baseline values for hydropower and irrigated agriculture and modelled the use of saved water for hydropower, irrigated agriculture and environmental flows. The model is not designed to optimise saved water use in the system. In contrast, the simulation approach allows for explorative scenario runs based on 'what if?' The model is designed for stakeholders to be able to ask questions on the merits of cooperation and explore cooperative policy options.

As the model is presently calibrated, it uses average market prices for irrigated agriculture and hydropower production, and as such this approach conceals regional differences. This means that the unit value of an extra hectare of irrigated agriculture and the value of an extra kWh of hydropower are similar throughout the sub-basins. This limits the explanatory power of sub-basin analysis. A further limiting factor is that the market and non-market monetary value of the marginal benefits from environmental flows are not estimated. This means that it is difficult to compare marginal benefits across hydropower, irrigated agriculture (which have monetary value estimate) and the improvement in ecosystem goods and services as a result of environmental flows (as no monetary value estimates are attached to the goods and services obtained as a result of the flows). However, a shadow value approach was used to indicate the cost of using saved water for environmental flows. The shadow value is computed to compare the cost of acquiring saved water for environmental flows from other productive uses in the basin (namely hydropower and irrigated agriculture).

6.2 Input and output variables in the model

The hydroeconomic simulation model is built in Excel and consists of a number of spread sheets and links between the spread sheets (for hydropower and irrigated agriculture). The model focuses on estimating monetary values of the marginal benefits of using saved water from WUE improvements in irrigated agriculture. The model is not calibrated to allow for reallocation of the baseline hydrological flow volumes. For illustration purposes, a front end view of the hydroeconomic model is presented in Figure 8. It displays Simulation 5 (see Table 9).

The context for the modelling is that there is some 'slack' in irrigated agriculture water use and that there is scope for WUE improvements in the sub-basins. The key variable that drives water saving is the irrigated agriculture WUE improvements. The model views that the resulting efficiency improvement will reduce water depletion in the sub-basins. This improved agricultural WUE enables the same irrigated agricultural yield to be produced with a lower volume of water and thus it will allow for a reduction in the volumes abstracted from the regulated flows in the main river stems.

While the exact WUE technique is not an input to the model, a common approach to improve irrigated agriculture WUE is to encourage the uptake of advanced irrigation systems (for example, drip irrigation, see Table 7) or improved management approaches. The level of uncertainty in the effectiveness of WUE in irrigated agriculture is a function of a number of variables including behavioural issues, water pricing, farmer experience, crop types, availability of extension services, and biophysical characteristics of the area (e.g. groundwater and surface water interaction), evapotranspiration and evaporation.

The model input variables for each sub-basin are:

- the irrigated agriculture WUE improvements resulting in a volume of saved water;
- the use of the saved water for additional productive uses: environmental flows; irrigated agriculture or hydropower.

The model output variables for each sub-basin are:

- the value of saved water used for hydropower production in USD (hydropower is treated as non-consumptive use and the flows are available for downstream users);
- the value of saved water used for irrigated agriculture in USD;
- the shadow value of saved water used for environmental flows; as the model is presently calibrated saved water used for environmental flows is treated as an abstraction. A shadow value of saved water use for environmental flows is computed as an indication of the cost of acquiring water from other productive uses in the sub-basins; and
- the volume of saved water that cascades to the downstream sub basin.

The following variables are *not* included in the model:

- the type of WUE improvement or the costs of WUE improvements;
- the market and non-market values of the use of environmental flow for wetlands restoration; coastal zone restoration or managing salinity;
- the multiplier effects of irrigated agriculture, hydropower production and use of environmental flows; and
- the baseline hydrological flows (are presented as background data only).

6.3 The Hydroeconomic model scenarios

In this section, outputs of some model simulations are presented for illustrative purposes. The results from simulations highlight the difference in the unit values of water use for irrigated agriculture and hydropower in each sub basin. They also look at the cost of allocating saved water to environmental flows. Based on the present model calibration, a number of simulations are presented in Table 9.

The simulation results illustrate that total value of saved water is higher when it is allocated to agricultural use. The baseline market value for currently generated irrigated agriculture products in the system as a whole is 4.8 billion USD and for hydropower it is 3.5 billion USD. This is in line with the baselines where the total values from agricultural commodities are higher than those from hydroelectricity.

Simulation 1, 2 and 3

Simulating water saving from a 30 percent WUE improvement in all sub-basins, can generate the marginal benefits from irrigated agriculture and hydropower up to 1.45 billion USD and the shadow values for environmental flows range from 181 million USD to 279 million USD.

When an equal allocation of the saved water is conducted to take into account the importance of multiplier effects resulting from hydroelectricity, for example (Simulation 1), the total value of saved water is roughly 20 percent less than the case when it is allocated solely for agricultural use (Simulation 2) and 80 percent higher than when it is completely allocated for hydropower production (Simulation 3).

Simulation 4 and 5

To address the problem of externalities, a comparison is made between setting aside environmental flow proportionately in each sub-basin (Simulation 4) and focusing the environmental flow in the sub-basins where the externalities are most severe, i.e. sub basin 5E and 6T, as in these sub-basins the majority of the regions marshlands exist (Simulation 5). The results show that a lower shadow value will be achieved when the environmental flow is generated in sub-basins 5E and 6T (i.e. Simulation 5). This is in contrast to Simulation 4 which generates environmental flow in all sub-basins. Simulation 5 generates an absolute environmental flow of 5 BCM to 5E and 6T only (2.5 BCM to each of these sub-basins). For sub-basin 5E, 2.5 BCM equals approximately 34 percent of the total saved water (6.57 BCM), leaving approximately 33 percent respectively for additional irrigated agriculture and hydropower. For sub-basin 6T, 2.5 BCM equals approximately 48 percent of the total saved water (3.90 BCM), leaving approximately 26 percent respectively for additional irrigated agriculture and hydropower..

The scenario runs demonstrate a significant increase in marginal benefits through the use of saved water for additional irrigated agricultural production or hydropower generation in all sub-basins and in selected sub-basins with high irrigation potential.

The scenario runs also demonstrate the shadow value of abstracting water for wetlands restoration/environmental flow (i.e. the lost opportunity of using water for irrigation or hydropower generation). The shadow value is a very conservative estimate of the benefits of environmental flow. The true value of the environmental flow could be significantly higher if the market and non-market value of the improvements as a result of the environmental flows were to be estimated.

The combined baseline analysis and hydroeconomic model indicate that there is significant scope for improving efficiency in irrigation and the simulations demonstrate this value in monetary terms at a system wide level for the ET region. There is scope, through improved WUE in irrigated agriculture, for generating more hydropower and at the same time gain more water for downstream management or for wetlands, salinity management and outflow at the terminus, by improving WUE in irrigated agriculture.

This does not mean that less agriculture products can be produced. On the contrary, output can be maintained (or even increased) by applying WUE measures.

There are some important caveats to the simulation results that shed light on further work that could be performed:

- Under normal circumstances, land available for irrigated agriculture is bounded by a maximum irrigation potential (i.e. there is a cap on the availability of land). For the purpose of developing the hydroeconomic simulation model we have assumed that the irrigated land is unbounded, i.e. there is no cap on the amount of additional land available for the expansion of irrigated agriculture. We also assume there are no changes in commodity prices.
- The multiplier effects of additional hydroelectricity, agricultural production or use of environmental flows are not taken into account. The values of these multiplier effects can be significant. For example, produced hydroelectricity might be delivered to some industries that generate high-valued commodities, or to households to meet their basic needs. Incorporating the multiplier effects to the hydroeconomic model can shift the balance of the values of using saved water in irrigated agriculture; hydropower and use for environmental flows.
- The model suggests a "rebound effect" in which saved water from increased WUE in irrigated agriculture is best allocated back to the agricultural sector. This insight should be taken with precaution. The model focuses on the monetary value that can be gained from increased efficiency of current agricultural water use. Thus, the agricultural water use component of the hydro economic model is treated as given and the current agricultural practices are taken as a constant, in contrast to the fairly detailed hydropower water use component of the model. With little knowledge on the exact sources of inefficiency of agricultural water use, i.e. farm level, choice of crops, irrigation canals, drainage systems, water quality expanding agricultural production merely on the basis of crop value might provide a perverse incentive of maintaining currently inefficient practices.
- The externality cost is not captured in the model. The ET basin is naturally vulnerable to salinity problems and there is a trend of increased salinity in the basin. This increased salinity impacts on the functioning of the ecosystems and crop yields. Without appropriate measures to address and mitigate salinity, the rebound effect that encourages further expansion in agricultural activity will only exacerbate the problem. In the end, this salinity problem can seriously threaten the agricultural productivity and put the current baseline agricultural value of 4.8 billion USD at risk.

HYDRO ECONOMIC MODEL OF THE EUPHRATES AND TIGRIS CATCHMENT AREAS														
						Allocation of saved water to…								
Sub-basin[1]	From	To	Agri. Flow[2] (BCM)	Agri water use eff. impr.[3]	Saved water (BCM)	Env. Flow %	Env. Flow BCM	Agriculture %	Agriculture BCM	Hydropower %	Hydropower BCM	Water cascading to downstream subbasin (BCM)[4]	Value of add. Hydropower[5]	Value of add. Agriculture[6]
1E	1E	2E	4,24	30%	1,27	0%	0,00	50%	0,64	50%	0,64	0,64	49 556 690 USD	69 240 000 USD
2E	2E	5E	3,11	30%	0,93	0%	0,00	50%	1,15	50%	0,47	1,15	9 410 990 USD	135 303 601 USD
3E	3E	2E	4,60	30%	1,38	0%	0,00	50%	0,69	50%	0,69	0,69	NO HYDRO	81 180 000 USD
4E	4E	2E	0,31	30%	0,09	0%	0,00	50%	0,05	50%	0,05	0,05	NO HYDRO	6 165 000 USD
5E	5E	1TE	21,91	30%	6,57	34%	2,63	33%	2,55	33%	2,17	2,55	16 627 646 USD	160 223 930 USD
1T	1T	2T	2,87	30%	0,86	0%	0,00	50%	0,43	50%	0,43	0,43	13 319 728 USD	46 575 000 USD
2T	2T	6T	1,27	30%	0,38	0%	0,00	50%	0,41	50%	0,19	0,41	7 635 266 USD	55 095 973 USD
3T	3T	6T	1,21	30%	0,36	0%	0,00	50%	0,18	50%	0,18	0,18	989 883 USD	24 615 000 USD
4T	4T	6T	1,22	30%	0,37	0%	0,00	50%	0,18	50%	0,18	0,18	NO HYDRO	24 615 000 USD
5T	5T	6T	3,04	30%	0,91	0%	0,00	50%	0,46	50%	0,46	0,46	6 563 410 USD	34 245 000 USD
6T	6T	1TE	12,99	30%	3,90	48%	2,46	26%	1,33	26%	1,01	1,33	2 125 306 USD	100 497 915 USD
1TE	1TE	2TE	0,20	30%	0,06	0%	0,00	50%	1,97	50%	0,03	1,97	NO HYDRO	116 302 262 USD
2TE	2TE	SEA	0,08	30%	0,02	0%	0,00	50%	1,00	50%	0,01	1,00	NO HYDRO	55 717 852 USD
										SUM			106 228 919 USD	909 776 533 USD
										TOTAL VALUE OF ADDITIONAL WATER				1 016 005 452 USD
										SHADOW VALUE OF ENVIRONMENTAL FLOW				286 811 420 USD

How to use the model

1) Choose the percent of improved water use efficiency in agriculture from the drop down list in column E.
2) Allocate the saved water to environmental flow, agriculture and hydropower by changing the percent in columns G and I.

Notes

[1] Subbasin The Tigris & Euphrates Basin is divided into 13 subbasins (map of the catchment area in Excel-sheet “”Catchment areas”” below)
1E-5E is in the Euphrates
1T-6T is in the Tigris
1TE-2TE is Tigris & Euphrates

The basins were compiled according to topography and water flow and based on Remote Sensing SRTM data. The Shuttle Radar Topography Mission produced the most complete, highest resolution digital elevation model of the Earth. 90 m grid, with linear vertical absolute height error of less than 16 m, linear vertical relative height error of less than 10 m.”

[2] Water use for agriculture irrigation (Billion Cubic Metre/Year)
Area of irrigated agriculture* irrigation factor for each catchment area.

The area of irrigated land is based on the world irrigation map http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm from 2000 and updated with Land cover classification GLOBCOVER 2005, based on Satellite Remote Sensing Data, MODIS/MERIS data (www.gofc-gold.uni-jena.de/).

The irrigation factor is 1000 litre/m2/year for potential evapotranspiration less than 1500 mm and 1200 litre/m2/year for potential evapotranspiration more than 1500 mm. The factors is based on expert knowledge.”

[3] Agriculture water use efficiency improvement in percent.

[4] The water saved in this subbasin plus the accumulated water savings from upstream subbasins that will cascade down to the next subbasin.

[5] Value of additional water for Hydropower (USD)
The value of additional water for Hydropower estimated in sheet “Euphrates Hydropower” and “Tigris Hydropower”.
The economic values and the Hydropower modeling is based on expert knowledge (the energy price is 8 cents/kWh).”

[6] Value of additional water to be used for irrigation of agriculture (USD)
The value of additional water for agriculture estimated in sheet “Euphrates & Tigris Agriculture”.

Figure 8. Hydro-economic model front end view (examples Simulation 5).

Table 9 Baseline and Simulation Values

		Sub-basin				Baseline value (USD)	
Baseline values							
Agriculture Hydropower		All All				4.8 billion 3.5 billion	
Simulations							
		Sub-basin	**Use of saved water for agriculture***	**Use of saved water for hydropower***	**Use of saved water for environmental flow**	**Value of saved water (USD)****	**Shadow value (USD) of environmental flow*****
1	30% WUE improvement	Improvements made in all sub-basins	50%	50%	0%	1.15 billion	0
2	30% WUE improvement – all saved water used for agriculture	Improvements made in all sub-basin	100%	0%	0%	1.45 billion	0
3	30% WUE improvement – all saved water used for hydropower	Improvements made in all sub-basins	0%	100%	0%	214 million	0
4	30% WUE improvement – saved water spilt between agriculture, hydropower and environmental flow	Improvements made in all sub-basins	35%	35%	30%	788 million	515 million
5	30% WUE improvement – social planner simulates environmental flow of 2.5 BCM each to 5E and 6T each of both sub basins)	Improvements made in all sub-basins	50% in all sub-basins except 5E (33%) and 6T (26%)	50% in all sub-basins except 5E (33%) and 6T (26%)	0% in other sub-basins 34% in 5E and 48% in 6T	1.02 billion	286 million

* Only in corresponding sub-basins where efficiency improvements are made ** Figures are rounded *** Shadow value of water is computed by comparing the cost of acquiring water from other users in the associated sub-basin.

7. Future work

This study has provided evidence that benefits can be generated at a system wide level in the ET region from transboundary waters as a common pool resource. Transboundary water resources management is a regional public good and all riparian countries need contribute to its demand and supply to avoid further degradation of the system which could have major repercussions for the citizens and the ecosystems in the ET region and beyond. There are many barriers to overcome in order to achieve cooperative action in the ET region. This study recognises that these barriers exists and has not set out to identify how to overcome them. It has focused on providing evidence that cooperative action makes sense and that it could provide benefits to all riparian countries, depending on the opportunities to link policy objectives.

However, in order to formulate effective strategies to ensure effective cooperative action, the barriers to cooperative action and implementation have to be clearly identified first. This applies to both internal barriers and external barriers. Internal barriers include highly unequal income distribution, low-level and inefficient infrastructure, the role and level of financial markets, the development level of the education system, the prevailing ideological thinking including religion, natural resources endowment, the role of the state and the strength of the democratic process, the extent of corruption, and the degree of market failures. External barriers can be created by multinational or transnational corporate control over resources, patterns of international trade, the functions of international financing institutions, geopolitical interests and power of the states, and economic policies of the states. If stakeholders jointly analyse the barriers they face, they could identify and address obstacles early in the cooperative management and development process. The objective of the barrier analysis is not to challenge state sovereignty, but to enable basin countries to identify strategies to overcome foreseeable obstacles to ensure that preferred development opportunities can be implemented more effectively.

The study reference/observer group began to undertake a barrier analysis as a basis for identifying future steps. They identified the following issues:

- low economic growth;
- growing poverty;
- decrease in rural family income due to droughts;
- lack of employment opportunities;
- low demand for labour for work in agriculture, industry and services;
- labour migration from rural to urban areas;
- tension between ethnic and cultural groups;
- social welfare issues;
- degradation of the environment;
- low literacy;
- elderly farmers;
- high migration rates;
- increasing tensions at the local and regional levels due to water scarcity;
- tensions from former civil strife;
- rehabilitation of former war zones not taking place; and
- disputed borders.

All these dimensions contribute to a downward spiral and poor social capital to tackle common challenges. The role of water is said to be key, at all scales, to provide a positive spiral and promote an improved socio-economy at the rural, urban, local and national levels and in the ET region as a whole.

Based on the evidence presented in this study the reference/observer group has contributed the following possible steps to explore with the ambition to move towards cooperative action and realise some of the benefits from cooperation. The list is divided into three categories: institutional; capacity building; and investments. It was noted that cooperative steps should be listed for the short, medium and long term. In addition activities do not necessarily have to be implemented at the ET region wide level but can be implemented at smaller scales, such as sub-basins.

LT=Long term, MD=Medium term and ST=Short term.

Institutional issues

1. (LT) Analysis and improved effectiveness of institutional designs to deliver on regional public goods such as transboundary water resources management, energy markets, food production and ecosystems at sub-basin and ET region wide levels through:

a) (MT) joint research and development to improve efficiency and effectiveness of the systems,
b) (LT) learning and sharing agriculture technology and management experiences,
c) (MT) developing and design of regional markets for electricity (power pooling),
d) (MT) developing and design of regional markets for agriculture products,
e) (ST) developing and design of wetland restoration, salinity management and dust/haze mitigation programs and,
f) (MT) improving the management of old and new infrastructure for system wide benefits.

2. (ST) Utilization of existing regional economic frameworks to promote a political dialogue around effective and efficient water use.
3. (ST) Analysis of early warning and decision support requirements for interconnected sub-basin flood control and management.
4. (ST) Identifying a regional host for a common data centre and national focal points.

Capacity building

5. (ST) Improve the hydroeconomic model towards a "shared vision" including:

a) a full cost-benefit analysis of measures to drive irrigation efficiency improvements,
b) drawing the multiplier effects into the broader economy,
c) inclusion of data provided by the countries through joint work flows and,
d) investigation of water quality especially the impacts of salinization and wetlands degradation.

6. (MT) Cooperative modelling of the haze problem, its root causes and solutions.

7. (LT) Analysis of transboundary groundwater sources, users and conjunctive surface and groundwater interaction.

8. (ST) Development of a basin monograph, issues, knowledge base on basin and sub-basin scale water per capita issues, water for historic structures, climate change aspects.

9. (MT) Assess drought mitigation strategies for the basin, common early warning systems, models and scenarios.

10. (ST, MT) Detailed analysis and methodology development at sub-basin level to improve model at basin wide scale and drive investment dialogue at sub-basin level.

11. (ST) Undertake a study on social and cultural barriers to cooperation.

Investments

12. (ST, LT) Program to support improved agricultural water productivity:

a) Effectiveness and efficiency and modern irrigation strategies per sub-basin,
b) New cropping patterns basin wide – need to be studied, semi-arid areas, less water demanding crops and,
c) Rainwater harvesting technology deployment to improve rain fed agriculture.

13. (MT) Feasibility studies of wetland reclamation in priority areas of the basin, including cost-benefit analysis of those measures.

14. (ST, MT) Feasibility studies of rehabilitation of multipurpose hydraulic infrastructure, system wide planning and use of reservoirs.

15. (MT) Feasibility studies of interconnecting isolated power grids, development of power markets.

8. Conclusions

The objective of the study was to perform a baseline system-wide characterisation of key water users in the ET region and to develop a hydroeconomic simulation model. The data was retrieved using remote sensing technology, publicly available data and information as well as expert opinion. The use of a hydroeconomic approach allows for monetary estimation of the marginal benefits of using the saved water for productive uses and also the shadow value of using the saved water for alternative uses that are not priced in the market (such as wetlands).

Baseline values of irrigated agriculture and hydropower production were estimated. In addition a qualitative assessment of the wetlands, salinity and the sea coastline was performed. It is concluded that the sub-basins are sub-optimally managed which has resulted in the loss of significant wetlands and a significant increase in salinity levels, impacting on the ecological status and productive capacity of the region. The sub-basins are at risk and vulnerable to anthropogenic climate change. Based on the characterisation of the system, a rudimentary lumped conceptual hydrological model was developed to provide an estimate of the overall water flows in 13 sub-basins and is presented as background information. The baseline characterisation confirms that the sub-basins are highly regulated, with a significant number of large hydroelectric production facilities, in particular in the upstream part of the basin where precipitation is significant. In terms of storage capacity, there is significant capacity upstream, as demonstrated by the volume of water in sub-basin 1E versus the volume of agreed flow to sub-basin 2E (over a third of the total volume in 1E is held in 1E dams).

Following the baseline characterisation the focus of the study shifted towards modelling water use efficiency (WUE) in irrigated agriculture and estimating the marginal benefits (presented in monetary terms) of using saved water for additional productive uses, namely: irrigated agriculture, hydropower – and the shadow value for use as environmental flows. WUE could be achieved through system wide investments considering the regional dimension of water flowing across borders and binding countries together. The market and non-market values of the use of environmental flows were not estimated. The specific measures or instruments for WUE improvements or the costs of improvements were not modelled. In theory the same yield can be achieved with less water use over the long term by deploying a suite of tools including governance, management, economic and technical measures. The same amount of water can in principle double agricultural yields in the ET region but the cost to achieve this is probably very high. The abstraction of water from reservoirs and storage facilities needs to be reduced in order for it to be available for other purposes. In practice if water is abstracted for irrigation it is difficult to recuperate it for other uses. In addition there is a risk that putting saved water based on average crop value into an inefficient irrigated agricultural system, provides a perverse incentive to maintain currently inefficient practices.

The analysis confirms the significant opportunity to improve irrigated agriculture WUE. Model outputs illustrate how saved water can be used to generate more benefits for existing water uses through cooperative action.

The model, as presently calibrated, demonstrates that there is significant market value (using average market prices) of using saved water for additional irrigated agriculture. The caveats to this are that the model uses average market prices for irrigated agriculture and hydropower production, and as such this conceals regional differences. It is difficult to compare marginal benefits across hydropower, irrigated agriculture (which have a money value in the model) and the improvement in ecosystem goods and service as a result of environmental flows (as the market and non-market value of these goods and services have not been estimated). Furthermore, the multiplier effects of hydropower electricity generation and irrigated agriculture were not calculated and this could alter the distribution of the value of the marginal benefits of using the saved water.

The saved water from irrigated agriculture WUE improvements can be used to support restoration of wetlands, salinity management and improve the ecological quality of the sea coast. It can also be used for non-consumptive hydropower generation upstream. For salinity management and outflow at the sea coast, this comes at a cost to using the saved water for irrigated agriculture expansion. However, improving yield is possible with the same amount of water if correct management techniques are applied. Environmental flows for wetlands restoration has a relatively low shadow value when compared to both hydropower and irrigated agriculture, although it disproportionately impacts on irrigated agriculture expansion. The additional productive uses of the saved water are significant and are largely conjunctive across the sub-basins for a range of uses including, hydropower production, irrigated agriculture production, salinity, wetlands and the sea coast ecosystem goods and services.

In subsequent collaborative work a range of activities could be explored in order to support the development of cooperative options. These include institutional design, capacity building and investments across the short, medium and long term.

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